Geology and Mineral Deposits of the Cartersville District Georgia

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Geology and Mineral Deposits of the Cartersville District Georgia

By THOMAS L. KESLER

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A description of the mineral deposits and products from one of the oldest mining districts in the Southeastern States.

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GEOLOGY AND MINERAL DEPOSITS OF THE CARTERSVILLE DISTRICT, GEORGIA

By Thomas L. Kesler

ABSTRACT

The Cartersville mining district, 40 miles northwest of Atlanta, contains residual deposits of barite, manganese oxides, brown iron, ocher, and umber, and primary bedded deposits of specular hematite.

Mining of brown iron ore began about 1840, and the total output through 1943 is probably about 5,000,000 long tons. At least 20,000 long tons of umber have been shipped as iron ore in recent years. Manganese mining began not later than 1866; the recorded output of concentrates containing more than 10 percent manganese is 437,089 long tons, and there is probably only a small amount unrecorded. Ocher has been mined intermittently since 1877, and the total output is about 340,000 short tons. The mining of barite, begun about 1887, has been the most important of the mining industries since 1916; the total output of concentrates through 1943 is about 1,830,000 long tons, or about 24 percent of the total production of the United States.

Geologic formations.—The district is underlain by Cambrian metasedimentary rocks and gneisses derived from them. The Cambrian rocks were deposited as calcareous and noncalcareous shale, sandstone, amorphous hematite, dolomite, limestone, and variably calcareous siltstone; all the rocks have been recrystallized. In ascending order, they are divided into the Weisner, Shady, and Rome formations of Lower Cambrian age, and the Conasauga formation of Middle and Upper Cambrian age.

The Weisner formation consists principally of finely micaceous metashale containing scarce to abundant beds of quartzite and, less commonly, beds of metaconglomerate, metasiltstone, and crystalline carbonate rocks. The beds do not occur in any uniform stratigraphic order, and are exposed in a belt of parallel ridges that trend northward through the middle part of the district. The base of the formation is not exposed, but structure sections plotted from outcrops show that its thickness is more than 1,000 feet, probably more than 2,000 feet.

The Shady formation consists of variably siliceous specular hematite interbedded with dolomite. The age of the rocks is established by fossils, which occur in great numbers in some parts of the hematite beds and in residual, silicified parts of the dolomite. The beds of the Shady are conformable with those of the Weisner, but appear to be not everywhere present above them. The Shady formation is apparently broadly lenticular and has a maximum thickness of 30 feet, perhaps a little more. Where the Shady is absent, the Weisner is overlain by the Rome formation.

The lithology of the Rome formation is not uniform. In the extreme western part of the district, the formation consists largely of crystalline dolomite and limestone whose maximum thickness is about 1,800 feet. In the southeastern part, it consists largely of metashale whose thickness is at least 2,000 feet. The carbonate rocks and the metashale intergrade; the metashale adjacent to and overlying the carbonate rocks is calcareous, and irregular parts of it are weakly chloritic. To express the relation graphically, the original carbonate rocks were deposited as an irregular wedge or member thinning downward to the east, and the original shale was deposited contemporaneously as a complementary wedge or member thinning upward to the west. East of the main wedge, the carbonate rocks occur in lenticular bodies at and near the base of the metashale, and similar lenticular bodies of amphibolite farther east are believed to be strongly altered parts of the carbonate rocks.

The Conasauga formation consists largely of metashale containing unevenly distributed thin and thick beds of weakly calcareous metasiltstone. Its maximum thickness in the northeastern part of the district is 2,000 feet, but the upper part of the formation has been removed by erosion.

Feldspathic gneisses, derived through the metamorphism and replacement of the Cambrian rocks at the close of Carboniferous time, underlie much of the central and southeastern parts of the district. One variety consists largely of oligoclase, quartz, parallel mica laminae, and varying amounts of orthoclase. A second variety consists largely of andesine with smaller amounts of partly uralitized augite, biotite, quartz, and orthoclase and is layered rather than foliated. A third variety consists principally of orthoclase, most of which occurs in large porphyroblastic crystals and aggregates of such crystals. The orthoclase is enclosed in a groundmass whose mineral composition and structure are, in different places, those of either of the other gneisses. Orthoclase of similar habit has been found in the Cambrian rocks at 46 localities whose distance from the contacts of the gneisses ranges up to 6.5 miles.

The foliate and layered structures of the gneisses are invariably parallel to the bedding of the Cambrian rocks regardless of the local attitude of bedding or the orientation of contacts. Metashales adjacent to the gneisses contain much secondary feldspar and quartz, particularly where the contacts are oblique to bedding and foliation. The minerals of the gneisses have been irregularly deformed, but the effects of deformation have not been obscured by recrystallization. The strongest effects are strain twinning in orthoclase, strain shadows in quartz, and less commonly fractures without appreciable offsets. Orthoclase is characteristically veined and corroded by plagioclase and quartz.

Folding and faulting.—The Cambrian rocks are strongly folded, and the folds are accordant units of a broad belt of folds that, farther west, contain Carboniferous rocks. The least competent of the rocks were the shales, which at the time of folding made up the greater part of the geologic column in the eastern and central parts of the district. The shales, and the sandstones and siltstones interbedded with them, were compressed in parallel, more or less isoclinal folds oriented mostly northeast and overturned northwest. The carbonate rocks of the Rome formation were the most

competent; they thicken westward, were not so readily compressed, and were folded asymmetrically rather than isoclinally. Careful mapping and study of the rocks has shown no evidence of a major overthrust fault, which is shown on earlier maps of and including the district.

The folds are units of major anticlinoria and synclinoria that extend beyond the limits of the district. The folds in which the Weisner rocks are exposed constitute an anticlinorium. Synclinoria occur to the east and west of it; rocks of the Rome formation are exposed in the synclinorium to the east, and Knox dolomite in that to the west. The maximum thickness of rigid rocks adjacent to the district occurs in the area south and west of Cartersville, where the Rome formation is overlain directly by the Knox dolomite. The combined resistance of the carbonate rocks in that area to the compression of folds was greater than the resistance farther north, where the weak Conasauga rocks occur between the Rome and the Knox formations, and thicken northward. The local shortening was therefore less in the area south of Cartersville than farther north. The unequal shortening bent the folds of the Weisner anticlinorium, giving the axis of the major structure a sinuous trend, and developed rotational stress that formed steep faults oriented parallel and oblique to the trend of the axis.

Rock alteration not related to weathering.—The folding of the rocks was of flexural-slip type owing to the presence of shales interbedded with more competent rocks. Recrystallization apparently occurred during folding, for, with few exceptions, muscovite crystallized parallel to the bedding regardless of the attitude of bedding. The slipping movement in the beds of shale, between the more competent beds, is believed to have governed the orientation of the mica. A gradual though irregular westward decrease in the grain size of all the rock-forming minerals, which is measurable only in thin sections, suggests that heat essential for recrystallization was supplied from the east; water, also essential, is believed to have been present in the pore spaces and hydrous minerals of the original sediments. The uniform mineral composition of equivalent varieties of the rocks, except near the feldspathic gneisses, indicates an essentially uniform temperature of recrystallization. The westward decrease in the grain size of the minerals is interpreted to indicate that the period of time during which the temperature was maintained diminished with distance away from the source owing to diffusion.

The contact relations of the gneisses with the Cambrian rocks, and the mutual relations of the minerals in the gneisses, lead to the conclusion that the gneisses were emplaced during the final, sporadic movements of folding, and not by the forcible intrusion of igneous magma. The process apparently began with the deposition of orthoclase in Cambrian rocks, in greatest abundance in areas now underlain by the porphyroblastic gneiss. The orthoclase was irregularly strained and fractured, and was veined and corroded by plagioclase and quartz that were subsequently deposited; the plagioclase and quartz also were strained and fractured. Appreciable though uneven strain and fracture occurred only in the gneisses containing mica laminae, and the relation suggests that the nonplaty crystals interfered with slip along the laminae. The laminae and the uralitized augite are regarded as residual parts of the Cambrian rocks, but no inference is made regarding the relative importance of recrystallization, replacement, and lit-par-lit injection in the emplacement of the gneisses. The widespread influence of a watery solution is indicated, however, by the occurrence of orthoclase porphyroblasts and orthoclase-quartz veins in Cambrian rocks remote from the gneisses and inaccessible to a viscous fluid.

Primary ore and gangue minerals were deposited in the faults formed by the influence of unequal shortening, and in adjacent fractured calcareous rocks. These minerals include pyrite, galena, sphalerite, chalcopyrite, enargite, tennantite, vein quartz and carbonates, barite, and strengite. The barite commonly encloses all of the sulfides except enargite. The specular hematite does not occur in the vein deposits; it is confined to beds in the Shady formation, and was formed by recrystallization of an iron-rich mineral during the recrystallization of all the rocks. The deposition of the ore and gangue minerals in and adjacent to the faults began before faulting had ended, for the primary minerals are in places brecciated and enveloped in jasperoid subsequently deposited. The jasperoid consists of fine-grained quartz, which replaced most of the earlier vein carbonates and parts of the carbonate wall rocks and breccia fragments of the wall rocks.

Erosion and weathering.—Younger Paleozoic rocks presumably were deposited on and folded with those now exposed, but they have been removed by erosion since Carboniferous time. Nonuniform degradation is indicated by remnants of two levels of planation. One of these, the Piedmont Plateau surface, was formed in Cretaceous time or later. It is known as the Highland Rim peneplain, and has an altitude of 1,000 to 1,100 feet. Chemical weathering at the close of Highland Rim planation formed deep residual clays in areas underlain by calcareous rocks. Degradation was then resumed, with a new base level only 200 feet below the Highland Rim, and the Coosa terrace was formed in Tertiary time or later by selective erosion in the areas containing the residual clays.

As stream gradients in these areas approached the new baselevel, sandy clay and gravel were deposited in the lower valleys. Aggradation advanced upstream with alluvium supplied by headwater erosion and reached the headwater valleys, checking the removal of colluvial debris from the adjacent slopes. Chemical weathering again became active, deepening the dissected residual clays. Post-Coosa erosion has removed most of the valley deposits and lowered the valleys about 100 feet below the Coosa terrace level. Much of the colluvium remains on the higher slopes as a blanket of red to yellow sandy clay containing boulders of jasperoid and quartzite and, in places, fragments of residual ores. The blanket pinches out at the upslope limit of the underlying residuum. In most places it is 2 to 25 feet thick, but in a few places it is as much as 90 feet or more thick where it appears to fill deep lime sinks.

Secondary mineral deposits.—Chemical weathering of the primary mineral deposits formed the secondary deposits. Solution of carbonate rocks and vein carbonates that enclosed primary barite freed the barite that remains in the residual clays. Brown iron ore was formed by the weathering of pyrite deposits in the carbonate rocks of the Rome and Weisner formations and the quartzite of the Weisner formation; siderite is reported to be the source in one of the larger mines, but this carbonate was not found during the present investigation. Ocherous and umberous clays and subordinate brown ore were formed by the hydration of the bedded hematite of the Shady formation. Some of the larger ocher deposits occur in weathered fault zones, and pyrite is reported in many mines no longer accessible; hematite and pyrite may therefore be the combined source of ferric hydroxide in many ocher deposits. The origin of the manganese oxide ores is unknown as no primary manganese mineral has been found. Their geologic associations suggest that the manganese was derived from the weathering of a primary mineral deposited contemporaneously with the other primary ore and gangue minerals.

The deposits of brown ore are near economic depletion, and the remaining ore probably is confined mostly to the environs of the present mines. Some of the deposits of pyrite that underlie the brown-ore deposits may have considerable future value. Some of the larger known deposits of ocher have been exhausted economically; all surface indications of ocher in appreciable amounts have been prospected and the deposits extensively mined. The reserves are probably small. The closely associated umber is available in large amounts in the weathered hematite beds of the Shady formation, but the reserve cannot be estimated without exploration, as the grade of the umberous clays is quite uneven. Reserves of the underlying specular hematite probably amount to hundreds of thousands of tons, but the ore can be mined only by deep underground operations, and must be crushed and beneficiated to eliminate quartz.

Many of the larger barite and manganese deposits are economically exhausted to depths of 50 to 100 feet. The remaining ore-bearing clays are for the most part covered by a deep layer of colluvium and extend to depths below the level of ground water. The mining of the deeply covered ores will require systematic exploration, more efficient handling of the clays excavated, improved concentration, and probably a gradually increasing price of concentrates.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Cartersville mining district, one of the oldest in the Southeast in continuous activity, is 40 miles north-northwest of Atlanta, in Bartow County, Ga. The location of the district is shown in figure 1.

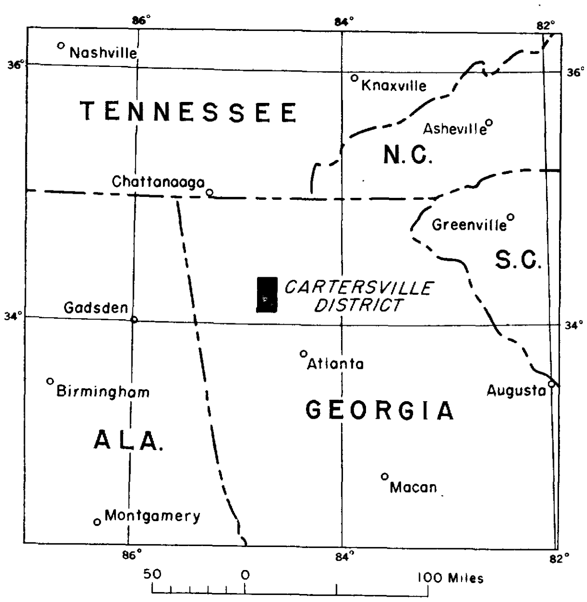

FIGURE 1.—Index map showing location of Cartersville district, Ga.

The latitude is a little more than 34° N. and the longitude a little more than 84° 30′ W. Mining has been carried on in an area 18 miles long and from ½ to 4½ miles wide. The topographic map of the district, prepared by the Geological Survey, includes an area of 177 square miles in which the mining area is a more or less median belt oriented approximately north.

Cartersville, whose population in 1943 is about 5,000, is adjacent to the southern part of the mining area, and is the center for supplies and shipping. The town is served by the Nashville, Chattanooga, & St. Louis Railway, the Louisville & Nashville Railroad, and the Seaboard Airline Railway. Two Federal highways provide a continuous paved route through the district: United States Highway No. 411 extends northward from Cartersville toward Knoxville, and United States Highway No. 41 extends southward from Cartersville toward Atlanta. Many graded and unimproved roads traverse all parts of the district except those of greatest relief.

PHYSICAL FEATURES AND WATER SUPPLY

The western part of the district, which has an average altitude of 850 feet, is moderately hilly and mostly cultivated. This part is included in the Appalachian Valley and Ridge physiographic province and is underlain principally by calcareous rocks. The eastern part, which has an average altitude of 1,000 feet, is quite hilly and mostly forested. This part is included in the Piedmont Plateau and is underlain principally by noncalcareous rocks.

Except in the extreme southern part of the district, the physiographically dissimilar western and eastern parts are separated by an irregular belt of ridges and knobs, which is referred to in this report as the ridge belt. The maximum altitude in the northern part of the ridge belt is on Bear Mountain, 2,305 feet, and that in the southern part is on Pine Mountain, 1,552 feet. Nearly all the mines are in the ridge belt, which is mostly forested and is traversed by very few roads.

The northernmost part of the district is drained by Pine Log and Little Pine Log Creeks, tributaries of Oostanaula River. The rest of the district is drained by the Etowah River and its tributaries. The Etowah transects the ridge belt east of Cartersville and flows westward, joining the Oostanaula at Rome to form the Coosa.

The average annual precipitation is approximately 50 inches, and the time of minimum rainfall is during the autumn months. Headwater streams in areas underlain mostly by noncalcareous rocks commonly carry year-round runoff, but those in areas underlain mostly by calcareous rocks are commonly dry during the summer and autumn. Most parts of the ridge belt are underlain by calcareous rocks; hence there is a scarcity of surface water for mining purposes during the season when operating conditions are otherwise most favorable. The calcareous rocks are deeply weathered to residual clays, and the depth to a dependable supply of ground water in those clays is rarely less than 50 feet, commonly 100 feet or more except near the larger streams having year-round flow. Mine operators have drilled a few wells having yields reported to exceed 100 gallons per minute.

Barite mining, the most active of the mining industries, is carried on mostly near the Etowah River, which furnishes an abundant water supply. The Water Resources Branch of the Geological Survey maintains a gaging station 3 miles east of Cartersville, and records of discharge have been kept since September 1938. The following data have been furnished by M. T. Thomson, district engineer in Atlanta:

The drainage area above the station is 1,110 square miles, and the datum of the gage is 686.92 feet above mean sea level. During the 5-year period 1939-43 the maximum discharge was 18,400 second-feet, and the minimum was 270 second-feet, but higher and lower values are probable for earlier floods and droughts. The average discharge during the 5-year period was 1,406 second-feet, a yield of 1.27 second-feet per square mile. This is equivalent to an average runoff of 17.19 inches a year.

A gaging station is maintained also at Canton, about 32 miles upstream from Cartersville, and at Kingston, about 22 miles downstream. The area between Canton and Cartersville is in the Piedmont Plateau, and that between Cartersville and Kingston is in the Appalachian Valley. The average yield of runoff per square mile of drainage area between Canton and Cartersville during the 5-year period was 0.99 second-feet, and that during the 10-day period of minimum flow in 1941 was 0.18 second-feet. The 5-year average yield between Cartersville and Kingston was 1.01 second-feet; the minimum yield 0.24 second-feet.

Although the average runoff in the Piedmont Plateau is approximately equal to that in the Appalachian Valley, the dry-period runoff is lower. This is surprising in view of the large amount of forested land on the plateau and the scarcity of surface water in the valley during dry periods. It is apparent that the channels of the Etowah and its larger tributaries have been cut through the residual clays in the valley and are fed directly by ground water. If the dry-period runoff is maintained substantially by ground water, the supply must be large and its movement relatively free through solution channels in the carbonate rocks. Ground water, therefore, is the logical source of water for the operation of mines that are not near the main streams.

FIELD WORK AND ACKNOWLEDGMENTS

Geologic mapping and study of mineral deposits in the Cartersville district were started by the writer in November 1936 and completed in August 1944. Other assignments have prevented prompt completion of the work, but the delay has been compensated by the opportunity to examine mines and drill cuttings made accessible or available as a result of the war stimulus. About 15 months were devoted to the field work, in intermittent periods, excluding cooperative activities involved in the government war program.

Every operator in the district has given assistance. Those who have been particularly helpful include the officials of Thompson-Weinman & Co., of the New Riverside Ochre Co., and of the Barytes Mining Co. The individual cooperation of J. M. Neel, W. S. Knight, C. H. Claypool, R. D. Hale, and F. D. Smith has been of especial value. Records of only a part of the mining and production in the district have been kept, but these were courteously furnished.

The writer made for the Corps of Army Engineers a petrographic study of core-drill samples from the Allatoona dam site on the Etowah River and was furnished the logs of many of the drill holes. The information thus obtained has greatly contributed to an understanding of stratigraphic and lithologic relations in the adjacent area.

Prof. S. J. Shand, of Columbia University, has made quantitative chemical analyses of several samples of the carbonate rocks, and the results of his work have been especially helpful in the consideration of possible sources of the manganese and iron oxide ores.

The writer has received the assistance and advice of other members of the Geological Survey in problems related to the structural geology, correlation of formations, and the identification of obscure minerals. G. F. Loughlin, E. F. Burchard, and H. D. Miser have contributed through discussions in the field and in the office. E. T. McKnight, Charles Milton, M. N. Short, Michael Fleischer, and Joseph Axelrod have identified some of the primary and secondary ore minerals by chemical, microchemical, and X-ray methods. Many questions regarding textures and mineral relations were discussed with C. S. Ross, W. T. Schaller, and C. F. Park, Jr.; F. W. Stead and M. H. Staatz assisted in the plane-table mapping of some of the manganese mines. The manuscript has been read critically by C. F. Park, Jr., and F. C. Calkins, and their comments and suggestions have been most helpful in the arrangement of the report, and in the treatment of geologic features.

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Since the seventies, many geologists and engineers have visited the Cartersville district, and most of them have published the results of their observations. The references, which are too numerous to be reviewed here, are listed below in chronologic order, and the most important of them are further discussed in the report. They contain descriptions and a few maps of the geology of the district and discussions of the occurrence, mining, beneficiation, and uses of the economic minerals. Casual references are not included.

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MINING AND PRODUCTION

The Cartersville district contains closely associated deposits of barite, manganese oxide ore, brown iron ore, ocher, umber, and specular hematite. Relatively little umber and specular hematite have been mined, but the other ores have been mined on a large scale.

Barite and the ores of manganese oxide and brown iron occur irregularly in deep residual clays and have been mined largely from open cuts, although considerable underground mining of manganese has been carried on. The specular hematite occurs in beds consistently in the same stratigraphic position. It has been mined from open-cuts, tunnels, and shafts. Most of the hematite in the zone of weathering has been hydrated, and its residuum comprises ocherous and umberous clays of uneven color. The brightest ocherous clays are mined for the production of refined ocher; both open-cut and underground methods are used. A few attempts have been made, largely by open-cut method, to produce the chocolate-brown clays, or umber, for use as iron ore.

The mining of brown iron ore began about 1840,[1] and there have been alternate periods of large-scale production and of little or no production. Up to about 1880, the entire output was used in local blast furnaces; there were nine of these, and their sites are shown in plate 1. The highest rate of production was attained after 1890, and the ore was shipped to furnaces elsewhere in Georgia and in Alabama and Tennessee. There has been only sporadic mining since 1923. The recorded output of iron ore from Georgia from 1889 through 1943 is 9,127,025 long tons, including a small but unknown amount of red hematite, or "fossil ore".[2] The estimated total output, from 1840 to 1943, is probably not more than 10,000,000 tons, and roughly half of the brown ore is believed to have been shipped from the Cartersville district.

According to Weeks,[3] manganese was first produced in 1866, although Watson[4] states that one of the deposits was mined as early as 1859. A large part of the early mining was of underground type to maintain a high grade of concentrates, and by this practice the upper parts of many of the deposits were selectively robbed without full recovery of the available ore. Mass mining, by power shovel and hydraulic giant, has accounted for most of the output since 1900; the most notable exception is the Will Lee underground mine described on pages 80-82.

The yearly sales of concentrates of all grades did not exceed 10,000 tons until 1917, and reached a peak of 30,875 tons in 1930, during the operations of the Manganese Corp. of America in the Aubrey area. Most of the output of manganese has been of production in Georgia through 1943.[5] Although in- of limonite with the manganese oxides. The accompanying chart, (fig. 2) shows the recorded yearly

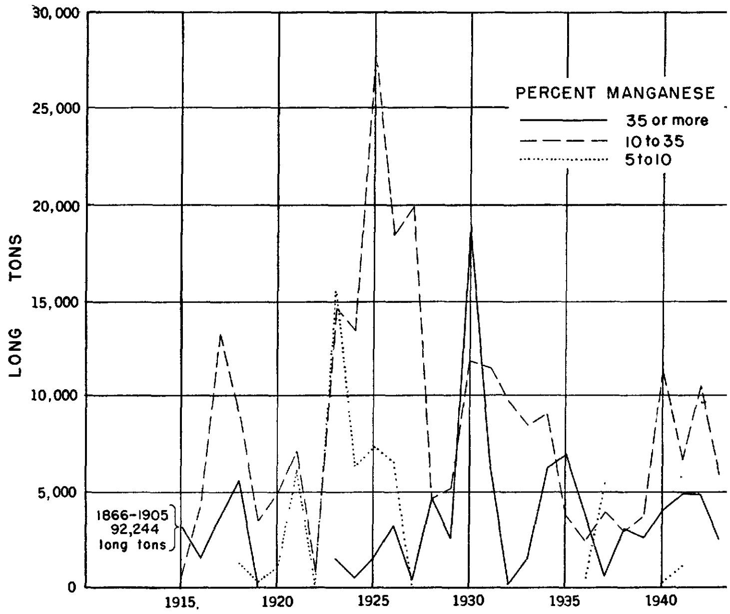


FIGURE 2.—Chart showing recorded yearly shipments of manganese concentrates from Georgia, essentially from Cartersville district.

complete, the record probably includes all but a minor part of the total output, nearly all of which has come from the Cartersville district. The recorded output amounts to 187,637 long tons of concentrates containing 35 percent or more Mn, 249,452 long tons of 10 to 35 percent Mn, and 52,262 long tons of 5 to 10 percent Mn.

Ocher was first mined in the district in 1877.[6] The yearly production of Georgia, which is that of the Cartersville district, was published only from 1889 to 1914. The output during this period was 121,043 short tons with a total value of $1,286,630.[7] The principal producers have supplied information regarding their total output since 1914. The information is confidential, and only the aggregate amount, 200,031 short tons, can be given. Unrecorded production probably would not amount to more than 20,000 tons. The total output of refined ocher, therefore, from 1877 through 1943 is about 340,000 short tons.

Umber, which occurs in close association with ocher, was mined and shipped during the thirties as "soft" iron ore to be sintered. The total output from three mines was 20,000 long tons, or a little less.

The earliest recorded production of barite from

[1] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, pp. 27, 125, 1900.

[2] Information furnished by N. B. Melcher, Bureau of Mines, U. S. Department of the Interior.

[3] Weeks, J. D., Manganese: Mineral resources U. S., 1889 and 1890, p. 133, 1892.

[4] Watson, T. L., Preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, p. 90, 1908.

[5] Based on compilations furnished by N. B. Melcher, Bureau of Mines, U. S. Department of the Interior.

[6] Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, p. 67, 1906.

[7] Compiled from U. S. Geol. Survey Mineral Resources U. S., period 1889-93, and Ann. Repts., period 1894-99.

Georgia was in 1894, when there was a shipment of 60 tons.[8] The yearly output increased slowly to 31,027 tons in 1915, but was expanded sharply to 104,784 tons in 1916.[9] Barite mining has been the principal mining industry in the district since that time. The total amount of crude barite—all barite concentrates—sold or used by producers in Georgia from 1915 through 1943, except during the period 1931-34, is 1,882,824 short tons having a total value of $11,589,173.[10] This is essentially the mine production, and nearly all of it was mined in the Cartersville district. The barite is marketed in long tons, and the overall average value per long ton is about $6.89.

Allowing for unpublished figures that have been made available, and for estimated production of which there is no record, the total output of crude barite from 1894 through 1943 is approximately 1,830,000 long tons. This is about 24 percent of the total production of the United States since 1880, and its total value also is about 24 percent of that of the United States.

The date of the earliest mining of specular hematite in the district is unknown, and there is no record of the total output. The principal mining was done between 1875 and 1900. Most of the workings are quite shallow, their maximum depth according to local information being 200 feet. It appears that the total shipments amounted to 60,000 tons or more. Only two cars of the ore have been shipped in recent years.

Vein and placer gold deposits, mostly of small size, occur in the southeastern part of the district. They were mined intermittently to depths less than 100 feet during the past century, but there is no useful record of activities and no record of the production. The scanty information available is contained in Bulletins 4-A and 19 of the Georgia Geological Survey and in a paper by Anderson[11] describing the exploration of one of the mines in 1932. No additional information was obtained during the present investigation.

RELATED INDUSTRIES

Three local firms process or consume ores produced in the district, and one firm manufactures stone products at a large quarry west of the mining area.

Thompson-Weinman & Co., whose principal business is the production of ground marble, operates a 21-table concentrating plant which is a unit of the Paga Mining Co.'s barite mill. The table concentrates ordinarily contain 92 to 94 percent barite, and are ground for use in high-gravity muds for oil-well drilling. The company is constructing a 5-cell froth-flotation plant with an hourly capacity of 20 to 24 tons of feed. The feed is expected to comprise the table concentrates, whose grade will be lowered for maximum ultimate recovery, plus tailings that contain more than 15 percent barite. When in operation, the flotation plant will produce all concentrates to be ground for high-gravity muds except jig concentrates containing less than 94 percent barite.

The Chemical Products Corp. consumes an undisclosed amount of barite concentrates in the manufacture of its principal products: barium carbonate and barium chloride. Two grades of barium carbonate are produced: the higher-grade form, known as the "sulfur-free," and the lower-grade, called the "free-flowing." Other products are sodium sulfide, sodium hydrosulfide, and ammonium sulfide. The company has been in operation since 1933. The consumption of barite has been fairly uniform since that time and is expected to continue so during the near future.

The Burgess Battery Co. operates a plant for the electrolitic production of MnO_2 used in the manufacture of dry-cell batteries.[12] The plant has consumed approximately 2 tons of ferruginous manganese ore per day since it was put in operation in April 1943. The ore is soft and unwashed, or "dry-mined," and contains an average of 30 percent Mn. The use of such ore has been found to be economical, and the rate of consumption is expected to remain stable, if not to increase, in the future.

The Ladd Lime & Stone Co. operates a quarry in the Knox dolomite, 2 miles west of Cartersville. The quarry is located at the east end of Ladd Mountain, and is said to have been in operation continuously since 1866. The quarry face is about 800 feet long and 250 feet in maximum height. It exposes thin- to thick-bedded dolomite that strikes north and dips gently west. The rock is reported to contain an average of 38 percent $MgCO_3$. Crushed stone, a principal product in the past, is no longer produced. All the better-grade stone now being quarried is processed in a large plant that includes six vertical kilns and one rotary kiln. The products, in the order of quantities produced, are dolomitic hydrated lime, prepared masonry mortar, and burnt agricultural lime.

GEOLOGIC FORMATIONS

CAMBRIAN METASEDIMENTARY ROCKS

Most of the Cartersville district is underlain by Cambrian rocks that are finely crystalline. Their

[8] Parker, E. W., Barytes, in Mineral resources of the United States, 1894: U. S. Geol. Survey 16th Ann. Rept., pt. 4, p. 701, 1895.

[9] Hill, J. M., Barium, in Mineral resources of the United States, 1916: U. S. Geol. Survey, p. 243, 1919.

[10] Compilations furnished by Oliver Bowles, Bureau of Mines, U. S. Department of the Interior.

[11] Anderson, C. S., Gold mining in Georgia: Am. Inst. Min. Met. Eng. Trans., vol. 109, pp. 61-68, 1934.

[12] The Cartersville plant of the Burgess Battery Co. was discontinued during the latter part of 1945.

origin and age are shown by sharply bedded structure, stratigraphic succession, and a few fossils. The rocks were originally shale, sandstone, magnesian limestone, siltstone, amorphous hematite, and conglomerate, which were deposited in more or less horizontal beds. All were subsequently folded and recrystallized, undergoing what is commonly referred to as low-grade metamorphism. The process has not obscured the interbedded relation of the different types of rocks, and the terms used herein denote clearly evident origin. Quartzite designates recrystallized sandstone, and the terms crystalline dolomite and crystalline limestone are self-evident. The less commonly used terms, metashale, metasiltstone, and metaconglomerate are used in preference to terms which fail either to give a proper understanding of origin or to indicate that the rocks have been metamorphosed. The recrystallized hematite is of the specular variety and occurs in beds; it is referred to simply as specular hematite.

The Cambrian rocks exposed in the Cartersville district have a total thickness of at least 4,500 feet, and comprise formations of Lower, Middle, and Upper Cambrian age.

WEISNER FORMATION (LOWER CAMBRIAN)

DISTRIBUTION

Owing to the presence of much quartzite, the rocks of the Weisner formation are more resistant to weathering than those of the other formations, and they crop out in the higher parts of the district. The rocks underlie a large part of the ridge belt, which trends northward along the west side of a large area underlain by feldspathic gneisses. This belt extends from the vicinity of Emerson to and beyond Bear Mountain. The areal distribution of the Weisner formation and its contact relations with the other formations are shown on the accompanying geologic map, plate 1.

LITHOLOGY

The Weisner formation consists principally of metashale but contains many beds of quartzite and a few beds of metaconglomerate, metasiltstone, and crystalline dolomite and limestone. These rocks occur in the metashale in no regular stratigraphic order, and their relative abundance varies.

The metashale consists chiefly of thin layers of very fine-grained muscovite, which in places contain dusty graphite, or finely disseminated quartz, or both. The layering of the rock and the cleavage of the muscovite are parallel to the beds of other rocks. The metashale is dark gray and brittle when fresh but becomes white to buff and very soft after weathering.

By far the greater part of the quartzite is fine-grained. The rock is dark gray where fresh and light gray to white where weathered. Most of it is vitreous and consists almost entirely of quartz, which occurs in angular, interlocking grains. (See pl. 2*A*, *B*.) Irregular parts of many beds of the quartzite are coarse-grained and commonly contain large ragged patches of veinlike quartz, which blend into the rock. The coarse texture is evidently the result of more thorough recrystallization, for the quartz has the same interlocking relation as that of the fine-grained rock. The quartzite in a few places is obscurely cross-bedded, but this structure is too scarce and too weakly developed to be of value in determining the order of deposition of the beds. A unique occurrence of pseudo ripple marks in a shear zone oblique to bedding has been described and illustrated by Ingerson.[13]

Some beds of the quartzite have a rather dull appearance even where fresh and contain various amounts of fine-grained muscovite and feldspar. This variety was originally silty to arkosic sandstone, and the quartz commonly occurs in rounded grains clearly of detrital origin. The muscovite is identical with that which constitutes the associated metashale, and was derived from clayey constituents. It is not clear whether the feldspar is detrital or a product of recrystallization. It consists of both potash and soda varieties and occurs in separate, minute, angular grains rather evenly distributed through the rock. Its habit differs from that of the late potash feldspar, which was locally deposited in all types of the Cambrian rocks (see pp. 40-42), and from that of detrital potash feldspar in the metaconglomerate described below. Some of the fine-grained feldspathic rock contains disseminated calcite or dolomite and much muscovite, and quartz is a prominent but not the dominant constituent. This variety is similar to the metasiltstone, described on pages 18-19, which is very common in the Conasauga formation.

The metaconglomerate, which occurs in a few random beds in the Weisner formation, cannot easily be identified in the field, although conglomerate texture is readily apparent in thin section. Field identification is difficult because the pebbles are small, consist mostly of quartz, and are commonly obscured by a coarsely recrystallized quartz matrix. The writer has found only one outcrop where the rock can be identified in place without question. This outcrop is on the east slope of a low hill half a mile southwest of the Blue Ridge mine. The texture and composition of the rock are illustrated in plate 2*C*, *D*.

A very few of the beds of metaconglomerate contain a great deal of potash feldspar, but clastic origin is not always apparent in the field, because pods of

[13] Ingerson, F. E., Fabric Criteria for distinguishing pseudo-ripple marks from ripple marks: Geol. Soc. America Bull., vol. 51, pp. 565-566, pl. 2, 1940.

secondary feldspar in places occur in the Cambrian rocks. (See pls. 11 and 12.) The secondary feldspar occurs in quite local parts of beds, however, and mostly in metashale. In general, it is safe to conclude that the feldspar is detrital if it occurs uniformly throughout a well-defined bed whose other main constituent is quartz, and if the feldspar and quartz, individually or interlocked, form relatively large rounded bodies separated by smaller rounded bodies or angular grains of quartz.

The Weisner formation contains beds of pure and impure crystalline dolomite and limestone, but the relative abundance of carbonate rocks is unknown owing to their susceptibility to weathering. They are known in greatest amounts at the Allatoona dam site on the Etowah River, 0.3 to 0.5 mile below the mouth of Allatoona Creek. There is only one small exposure of the carbonate rocks, on the south bank, but of many holes drilled by the Corps of Army Engineers the cores from 32 have shown that those rocks are common at depth. The beds and continuous sections of the carbonate rocks range from less than a foot to 95 feet or more in thickness, and they are interbedded in random succession with the calcareous and noncalcareous metashale, metasiltstone, and quartzite, which make up most of the Weisner formation in that vicinity. Dolomite and metashale of the Rome formation overlie the Weisner rocks in the adjacent area, and the occurrence of carbonate rocks in the Weisner formation suggests a local lithologic transition.

The carbonate rocks at the dam site are fine-grained and light to dark bluish gray. Their effervescence in hydrochloric acid is vigorous to meager, showing a considerable range in the content of dolomite. Much of the rock contains abundant fine-grained muscovite like that in the metashales. Bedding is sharply defined in core samples of the associated rocks (see pl. 3*A*) and in adjacent exposures along the river. The muscovite in the carbonate rocks and the metashale is oriented mostly parallel to the bedding.

Crystalline limestone in the Weisner formation crops out in a ravine on the south slope of Pine Log Mountain. The limestone is interbedded with metashale and quartzite and is at least 10 feet thick. The amount of outcrop, however, is not a reliable criterion of the quantity of rock present, for the limestone weathers rapidly in contrast to the rocks with which it is interbedded. The limestone contains much fine-grained muscovite, quartz, and plagioclase, and effervesces freely in hydrochloric acid. There is also a small area 2.2 miles farther south containing float boulders of pyritic, silicified limestone or dolomite, but the carbonate rock does not crop out.

The carbonate rocks known in the Weisner formation, at the two localities just described, are outlined as well as can be inferred on the geologic map, plate 1. At both localities, the carbonate rocks clearly inter-grade with the metashale that makes up such a large part of the formation. It is possible, therefore, that micaceous carbonate rocks are fairly common in the Weisner, although this cannot be determined from outcrops. The metashale in many exposures consists only of leached micaceous laminae that may or may not have contained carbonate minerals. This is particularly true of the metashale exposed in the bluffs along the river at the dam site.

The presence of carbonate rocks in the Weisner formation has not previously been reported as far as the writer is aware. Also unreported is the occurrence of lenticular beds of dark rocks in the Weisner formation in Warner Mountain, Ala., 2.5 miles northwest of Esom Hill, Ga. These rocks occur in weakly metamorposed shale that has been mapped as Weisner,[14] for a distance of at least half a mile along Alabama State Highway No. 74. They have a decidedly pyroclastic appearance and are noncalcareous, but they have not been studied in detail. No similar rocks have been seen in the Weisner formation in the Cartersville district, and the occurrence is mentioned here to emphasize the wide lithologic range of the formation as a whole.

STRATIGRAPHIC RELATIONS AND THICKNESS

The Weisner formation as shown on the geologic map includes the Weisner quartzite and Pinelog conglomerate of Hayes,[15] whose interpretation of its stratigraphy have been accepted in general by subsequent workers. The reasons for grouping these rocks together, and Hayes' reasons for dividing them, are discussed on pages 30-33. In brief, everywhere that they are exposed these rocks have the lithologic features just described, and they are structurally continuous in the areas in which they are shown in plate 1.

The rocks of the Weisner formation crop out only in the ridge belt, in anticlinal folds and are overlain conformably on the flanks of the folds by the rocks of the other Cambrian formations. The quartzite is particularly resistant to weathering; consequently, the Weisner rocks are exposed in the higher parts of the ridge belt. Most of the folds are strongly compressed, and the base of the formation is not exposed. As no beds or other horizon markers that are persistent and distinctive have been recognized, it has not been possible to determine the stratigraphic thickness of the exposed part of the Weisner by field measurements. It is clear, however, from the structure sections based on the attitude of bedding in

[14] Alabama Geol. Survey, Geologic map of Alabama, 1:500,000, 1926.

[15] Hayes, C. W., Geological relations of the iron ore deposits in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, pp. 403-419, 1901.

scores of outcrops that the thickness is certainly more than 1,000 feet, and probably is 2,000 feet or more.

The Weisner formation contains no fossils and is dated on the basis of its conformable stratigraphic position beneath the fossiliferous Shady formation. The position corresponds to that of the Weisner as mapped by Butts[16] in Alabama. McCallie[17] collected fossils from bedded specular hematite at the Roan mine and erroneously reported that they were from the Weisner formation. The hematite is now known to be a part of the Shady formation, and Resser[18] has identified the fossils with the Shady fauna.

The quartzite contains, quite locally, rodlike bodies, broadly elliptical in cross section with a major diameter of 0.2 inch or less, which consist of fine-grained quartz like that of the matrix. These rods have been called *Scolithus* tubes[19] and have been found by the writer at 12 localities. The rods are parallel and are oriented at angles from 40° to 90° to the bedding. Without exception, the enclosing quartzite contains two sets of closely spaced *s* planes, which consist of joints in most specimens, and of shear planes in a few. The *s* planes intersect at angles ranging from 30° to 60°, and the rods invariably occur at and parallel to the intersections.

These rods may be, as supposed, sand-filled worm borings, but it is questionable whether such weak structures could have survived the intense folding of the original sandstone. It is also doubtful that such structures, if they did survive, would govern the orientation of joints and shear planes formed dynamically. It seems just as likely that the position of the rods was governed by the *s* planes. Longitudinal and transverse views of a typical specimen are shown in plate 3*B*, *C;* the directions of the *s* planes are shown in the transverse view. The accompanying diagrams illustrate, in cross section, the possible mechanical origin of the rods. Plane AB is offset slightly by differential motion along plane CD. If similar slight motion then occurred along the segments of the original AB plane, the offset obstructing the motion might be isolated by local shear planes deflected to join the segments.

[16] Butts, Charles, The Paleozoic rocks, in Geology of Alabama: Alabama Geol. Survey Special Rept. 14, p. 63, 1926.

[17] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, p. 124, 1900.

[18] Resser, C. E., personal communication.

[19] LaForge, Laurence, The Cartersville district, in Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, p. 42, 1919.

SHADY FORMATION (LOWER CAMBRIAN)

DISTRIBUTION

The Shady formation conformably overlies the Weisner formation, but it is lenticular and therefore not everywhere present. Its rocks are strongly weathered near the surface, and their residuum underlies long, sinuous, and very thin belts along the upper contact of the Weisner rocks. As the Weisner formation crops out principally in the higher parts of the ridge belt, the striplike outcrops of the Shady formation are mostly on the slopes of the ridges, and parallel to their crests. (See pl. 1.) The outcrops are obscured by soil and colluvium, and sections of the formation are exposed only in mine and prospect openings. The southernmost outcrop is on Bartow Mountain, 0.8 mile southeast of Emerson, and the northernmost is on the headwaters of Stamp Creek, 2 miles southeast of Hanging Mountain.

LITHOLOGY AND FAUNA

The residual products of the weathering of the Shady rocks remain in place, and their character indicates that of the unweathered rocks. The products of weathering are sharply bedded ocherous and umberous clays containing various proportions of unhydrated hematite, secondary limonite, and residual masses of jasperoid. Most of the beds range in thickness from a fraction of an inch to a foot, and the bedding planes are not distorted.

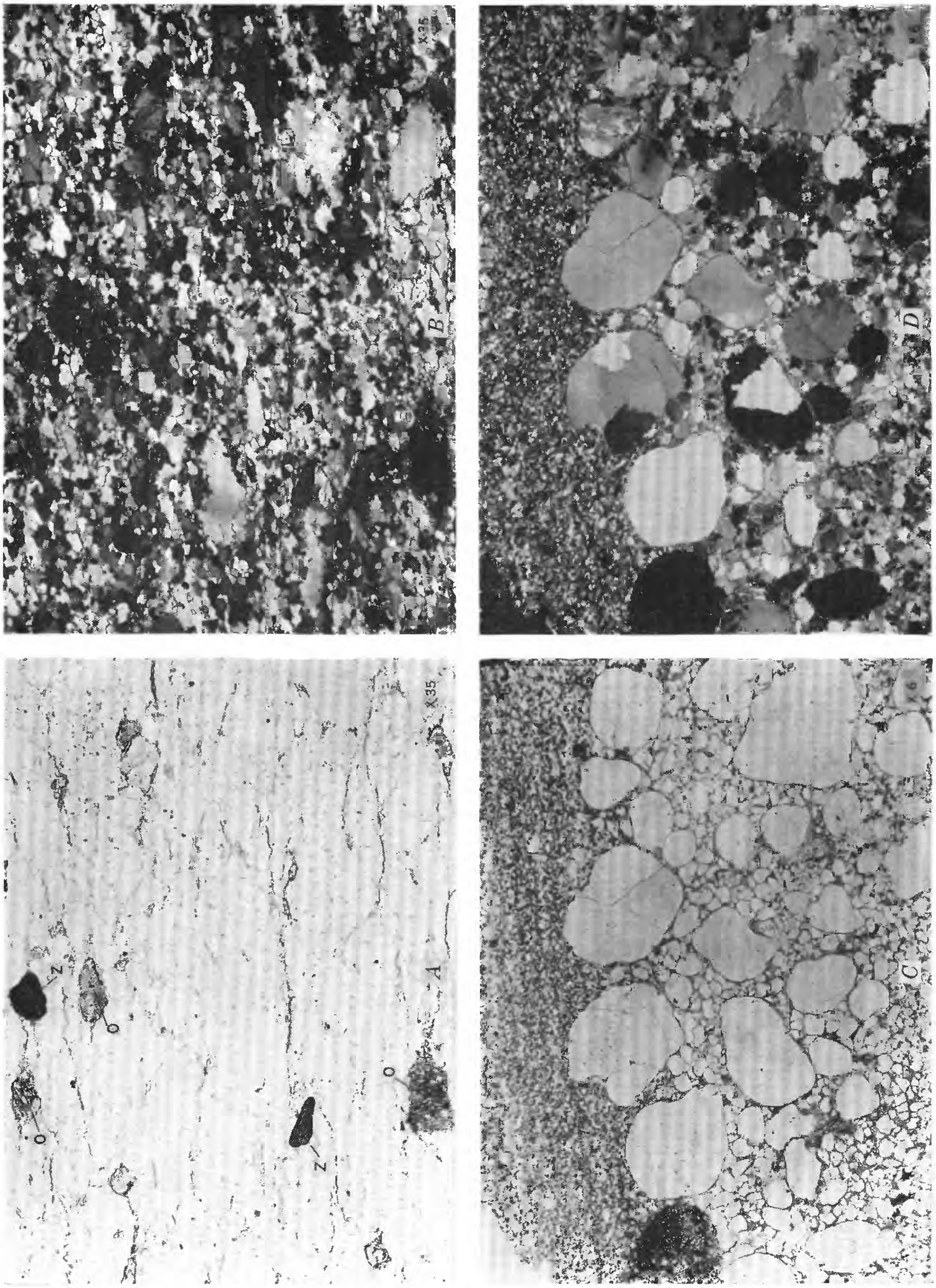
The clay beds that are most ferruginous contain the residual masses of unhydrated hematite, and the bedding of the clay and that of the hematite are parallel. The hematite grades into the clay, and the transition is obviously the result of hydration during weathering. The least ferruginous clay beds are identical with those residual from the overlying dolomite of the Rome formation and contain the residual masses of jasperoid which, throughout the district, occurs only in the residuum of carbonate rocks. The residual materials indicate, therefore, that the rocks below the zone of weathering consist of thinly interbedded hematite and dolomite.

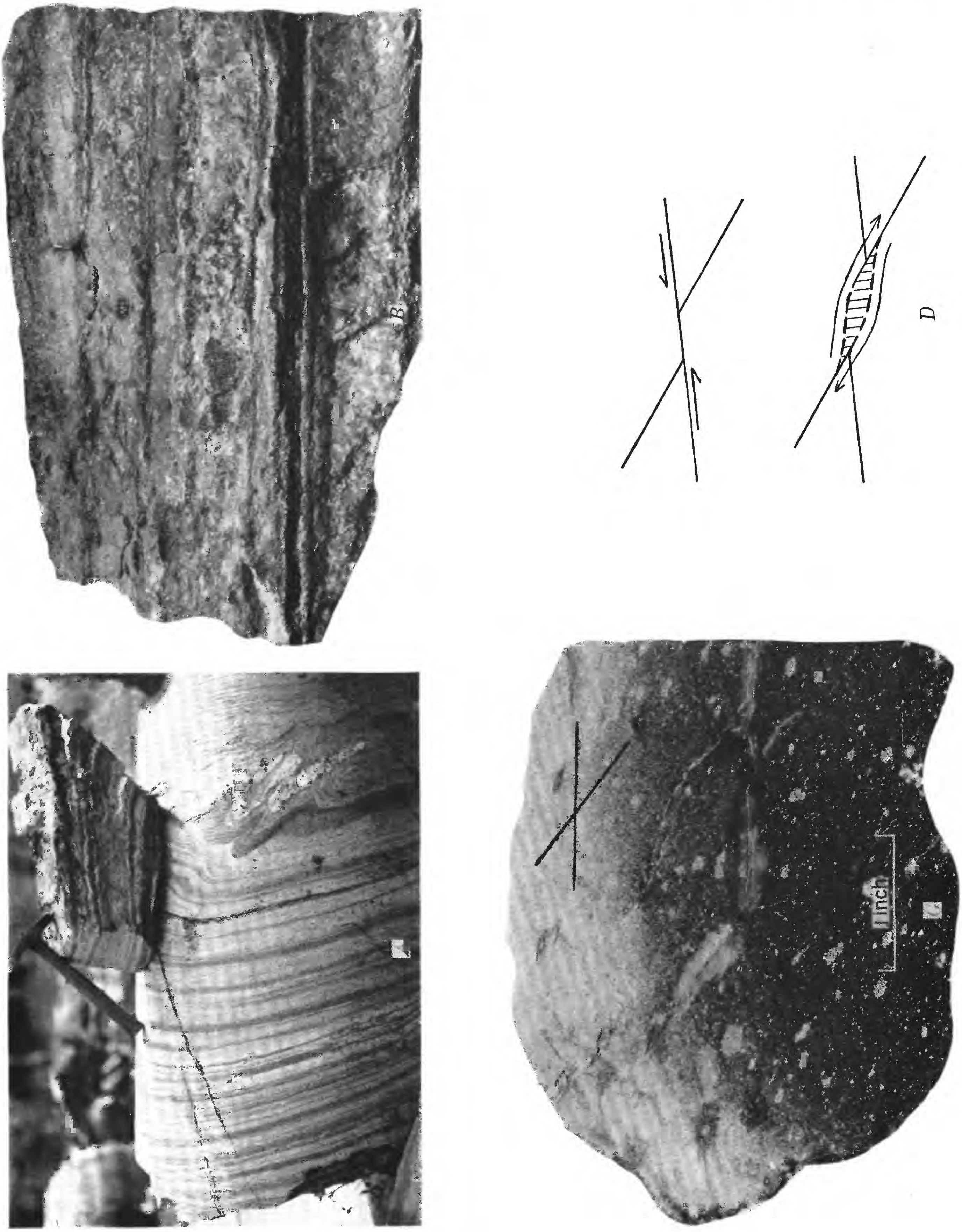
There is no regular succession of beds in those sections of the formation that have been studied. Incompletely hydrated hematite is directly in contact with the uppermost quartzite bed of the Weisner formation at a small brown-ore mine 0.6 mile southwest of the Dobbins mine, and in some exposures at the Roan mine. In other exposures at the

EXPLANATION OF PLATE 2

A, B, Photomicrographs of fine-grained quartzite of the Weisner formation. *A*, With plain light, showing a little detrital zircon (*Z*) and orthoclase (*O*). *B*, With crossed nicols, showing interlocking texture of the quartz.

C, D, Photomicrographs of metaconglomerate of the Weisner formation. *C*, With plain light, showing sharp outlines of pebbles. *D*, with crossed nicols, showing typical interlocking texture of quartzite (above) and composite mineral character of some of the pebbles.


B
X35
D
A
X35
Z
O
C
X6


B
D
1 inch

Roan mine, however, the hematite is separated from the quartzite by a few feet of clay clearly residual from dolomite.

Some of the clay residual from dolomite contains small nodules of a manganese oxide mineral of psilomelane type. The nodules occur quite irregularly, and show no consistent relation to any horizon or bed. They are rarely abundant enough for even small-scale mining.

The residual beds of hematite consist of fine-grained specularite and quartz in very uneven proportions. Some parts of the beds constitute high-grade iron ore, containing 60 percent or more of iron (see p. 89), but the dumps left from early mining contain much rock in which quartz is more abundant than hematite.

The quartz occurs in minute angular grains, but the hematite is platy to thickly tabular, and is oriented parallel to the bedding. Much of the higher grade hematite, containing only minor amounts of quartz, is fissile like the metashales of the underlying and overlying formations. Thick tabular crystals of hematite occur in the fissile ore, much as feldspar porphyroblasts occur in some of the metashales. Most of the hematite ore is nonmagnetic, but some specimens are weakly to rather strongly magnetic. A polished section of the magnetic ore shows thickly tabular hematite crystals enclosed in a matrix of platy crystals, but no magnetite. The crystals of both types are strongly anisotropic.

Fossils, which establish the age of the formation, occur sporadically in both the hematite and the jasperoid. The writer has collected the fossils at 25 localities in the ridge belt, from the vicinity of Emerson to the Blue Ridge mine. The specimens were obtained from mine dumps and from weathered residuum; consequently, it could not be determined whether the different forms occur in a definite sequence in the beds.

The fossiliferous hematite is quartzose, like much of the nonfossiliferous hematite, and the quartz forms the rock enclosing and filling the fossils, which consist entirely of specularite. The fossiliferous jasperoid shows organic remains mostly on the surface of the boulders, where they have been weathered into relief; the fossils consist of fine-grained quartz, as does the jasperoid, and the fossils and the matrix were evidently silicified contemporaneously. (See pp. 47-50.) Near the larger barite deposits, which occur in residuum of the overlying dolomite of the Rome formation, some of the clay residual from the beds of dolomite in the Shady formation contains barite. The Shady fossils occur sparsely in the barite, showing that both fossils and matrix were replaced by barium sulfate. The primary deposition of barite occurred in carbonate rocks. (See pp. 46-47.)

Fossils collected from the Shady formation were examined by C. E. Resser, of the Smithsonian Institution, who reported the following forms:

Archaeocyathids ("coral-sponges"): Most abundant of the fossils; probably five genera represented.

Brachiopods:
- *Acrothele* (?)
- *Kutorgina* sp.
- *Obolella* sp.
- *Yorkia* (?)

Gastropod: *Hyolithes* sp.

Trilobites:
- *Olenellus* sp.
- *Rimouskia* (?)
- *Wanneria* sp. (spine).

Part of the collection was also examined by Josiah Bridge, of the Geological Survey, who identified the trilobite, *Wanneria walcottana.*

A collection of fossils from the Parrott Springs mine has been examined by J. Brooks Knight and G. Arthur Cooper, of the United States National Museum, and found to contain the following forms: An undetermined archaeocyathid, *Nisusia* sp., *Semicircularea* sp., *Helcionella* cf., *H. rugosa* (Hall). The age indicated is Lower Cambrian.

In addition to the fossils, the hematite beds in places contain abundant small oolites. These, like the fossils, consist of specularite, and are similarly enclosed in fine-grained quartz. The interior also is filled with the quartz. The shape of the oolites is spherical to ovoid.

STRATIGRAPHIC RELATIONS AND THICKNESS

The contact between the Shady and Weisner formations is sharp and conformable, and the Shady is overlain in most places by dolomite, which has been regarded previously as the Shady dolomite. The status of this dolomite will be discussed in the section on carbonate rocks of the Rome formation, but the facts seem to require that the name "Shady" be restricted to the stratigraphic zone containing interbedded hematite and dolomite, as follows:

The lithology of the zone is unique.

At 24 of the localities at which Shady fossils have been found, the fossils occur in the rocks of the hematite zone immediately above the Weisner formation, or in weathered

EXPLANATION OF PLATE 3

A, Thirty-six inch calyx-drill core of metasiltstone and metashale from the Weisner formation at Allatoona dam site. Note white bodies of orthoclase and quartz where bedding is distorted.

B, C, D, Quartzite of the Weisner formation containing quartz rods. *B,* Longitudinal view. *C,* Polished face of transverse section; part of the quartzite is bleached from weathering. *D,* Diagrams illustrating possible origin by alternate movements along *s* planes.

residual jasperoid in the same stratigraphic position. At the one remaining locality the fossils occur in jasperoid on the crest of an anticline, and the Weisner is believed to occur there at very shallow depth.

As far as could be determined, the hematite zone is not consistently present where the top of the Weisner formation is exposed. It appears broadly lenticular and is overlain by Rome rocks, which, where the hematite zone is absent, directly overlie the Weisner.

The hematite zone, therefore, has a more distinctive lithologic character and occurrence than the underlying and overlying formations. Apparently it alone contains Shady fossils, and it is considered in this report to be the entire Shady formation in the Cartersville district. The Shady has a maximum thickness of at least 30 feet, but the effects of weathering make it impossible to determine its thickness with certainty. It may be that the formation as thus defined corresponds to the lower beds of the Shady dolomite as originally defined, which Stose[20] has discussed as a possible source of manganese oxide ores in the Appalachian Valley. There is no consistent relation, however, between the Cartersville manganese deposits and the Shady formation as defined above.

ROME FORMATION (LOWER CAMBRIAN)

The Rome formation consists of crystalline dolomite and limestone, and of metashale which is unevenly calcareous. The carbonate rocks and the metashale are separate members that intergrade laterally. In the western part of the district, the Rome formation consists mostly of the carbonate rocks and only the upper part consists of metashale, which in most places is highly calcareous. The carbonate rocks irregularly become thinner to the east, and taper out, as a continuous series, in the ridge belt. Eastward the metashale is calcareous in the zone of transition. In parts of the ridge belt, and east of it, the carbonate rocks occur in lenticular bodies at the base of the metashale. The relation of the two members is shown graphically in the structure sections on plate 1. The relation actually is stratigraphically transitional, or interfingering, rather than sharply lenticular, and indicates that sediments were deposited in Rome time in water whose depth increased westward.

The uneven occurrence of the two lithologic groups of the Rome rocks resulted in differences of aggregate strength and behavior during strong folding, and in differences of susceptibility to subsequent erosion and weathering. These are the principal controlling factors in the structural and economic geology and the physiography of the district.

CARBONATE ROCKS

DISTRIBUTION

Carbonate rocks of the Rome formation overlie the Shady and Weisner formations in most of the western part of the district. Unlike all other rocks in the district, which retain their structural characteristics even when strongly weathered, the carbonate rocks are destroyed by weathering owing to the leaching of the carbonate minerals. They are overlain by a thick and uneven mantle of residual clay, which contains most of the economic mineral deposits. The clay is easily eroded, and the areas underlain by the carbonate rocks are low in altitude and have little relief. The lowland areas in the ridge belt and in the area to the west are underlain mostly by the carbonate rocks. (See pl. 1.)

LITHOLOGY AND FAUNA

Outcrops of the carbonate rocks are rather scarce, but open-cut mining has exposed the rocks at many places. (See pl. 4*A*.) The rocks consist of crystalline dolomite and limestone. All are fine-grained and even-textured, and individual beds are uniform in color. The color ranges from light gray to bluish black but is for the most part dark bluish gray. Bedding planes are sharp, even, and parallel; there is no trace of any other primary structure.

Dark-gray chert of sedimentary origin occurs sparsely in thin lenses oriented parallel to the bedding. The lenses are rarely more than 4 inches across, and are best exposed in pinnacles of the dolomite in the Paga No. 1 mine.

The carbonate rocks in many places contain thin beds of metashale (see pl. 4*A*), which are more resistant to weathering than the dolomite and limestone. It is identical with the metashale of the Rome formation, described on pp. 14-15.

Samples of the carbonate rocks from 20 localities have been analyzed by S. J. Shand, of Columbia University, and the analyses are given in table 1. The proportions of CaO and MgO indicate the dolomitic character of the rocks and are of chief interest in connection with their lithology. The insoluble residues consist of quartz, muscovite, and pyrite in different proportions. The carbonate rocks are nowhere exposed in a continuous section, and the stratigraphic position of the samples analyzed can be designated only as low or high in the formation depending on the proximity of the outcrops to contacts of the Weisner or Conasauga formations. On this basis, samples 1 to 11 are from the lower part, and samples 12 to 20 are from the upper part. In pure dolomite, the proportion of magnesia to combined lime and magnesia is 41.76 percent. The proportions found in all the samples from the lower part of the series closely approach this figure, whereas those found in the samples from the upper part have a very wide range.

As the samples from the lower beds are uniformly almost pure dolomite, it might be inferred that com-

[20] Stose, G. W., Source beds of manganese ore in the Appalachian Valley: Econ. Geology, vol. 37, pp. 163-172, 1942.

TABLE 1.—*Analyses of carbonate rocks of the Rome formation from the Cartersville district*

No.	Character and source of sample	CaO	MgO	$\frac{MgO}{CaO+MgO}$	FeO	MnO	BaO	SrO	Insol. in HCl
1	Light-gray; thin-bedded. Outcrop 700 ft. NW. of Paga No. 2 barite mine	29.30	20.36	41.0	0.57	0.02	0	Trace	4.71
2	Dark, blue-gray; thin-bedded; muscovitic, quartzose, pyritic. Pinnacle in Paga No. 1 barite mine	18.67	11.75	38.6	1.61	.11	0	do.	38.60
3	Light-gray; thick-bedded; sparsely pyritic. Pinnacle in Section House barite mine	30.13	19.79	39.6	2.69	.26		do.	.55
4	Buff, weakly weathered, color abnormal; thick-bedded. Borrow pit 0.6 mi. SE. of Krebs barite mine	30.38	21.04	40.9	.24	.05	0	do.	.87
5	Dark, blue-gray; thick-bedded. Outcrop 0.4 mi. E. of Mosteller manganese mine	30.79	19.88	39.2	1.77	.14	0	do.	.29
6	Gray; thick-bedded; pyritic. Pinnacle in east Bufford manganese mine	30.45	20.79	40.6	.70	.08		do.	.79
7	Buff, weakly weathered, color abnormal; thick-bedded. Pinnacle in Little Aubrey manganese mine	30.49	21.70	41.6	.56	.06	0	do.	.12
8	Light-gray; thin- to thick-bedded; sparsely pyritic. Outcrop 0.6 mi. NE of Sugar Hill-Kinsey brown-ore mine	29.89	20.36	40.5	.77	.10	0	do.	2.76
9	Bluish-gray; thick-bedded. Outcrop 1,800 ft. WSW. of Bennett brown-ore mine	30.52	20.68	40.4	.43	.07	0	do.	1.44
10	Light-gray; thin-bedded. Outcrop 1,200 ft. N. of Bennett brown-ore mine	28.97	19.17	39.8	.08	.01		do.	7.65
11	Gray; thin-bedded. Outcrop at Vaughan manganese mine (No. 59)	29.50	20.37	40.8	.75	.08		do.	3.68
12	Bluish-gray; thick-bedded. Outcrop 0.6 mi. W. of brown-ore mine No. 1	29.81	20.87	41.2	.32	.02		do.	3.06
13	Light-gray; thin-bedded. Outcrop 1 mi. WSW. of Kelly brown-ore mine	30.64	21.02	40.7	.28	.02		do.	1.10
14	Dark-gray; thick-bedded. Outcrop 0.3 mi. SW. of Guyton brown-ore mine	50.87	3.40	6.3	.20	.02		do.	1.68
15	Bluish-black; thin-bedded; pyritic. Outcrop 1.4 mi. W. of Aubrey Lake	23.75	13.22	35.8	2.17	.05		do.	26.40
16	Light-gray; thin-bedded. Outcrop 0.9 mi. W. of Aubrey Lake	29.19	20.25	41.0	.31	.01		do.	5.42
17	Light-gray; thick-bedded. Outcrop 1 mi. W. of White	30.69	21.50	41.2	.04	.01		do.	.71
18	Dark-gray; thick-bedded; oolitic. Outcrop of the rock enclosing copper vein described on p. 92	54.33	.55	1.0	.29	.04		do.	1.63
19	White; thick-bedded. Outcrop 1 mi. N. of Oak Hill Church	28.08	19.52	41.0	.80	.10		do.	7.93
20	Dark-gray; thick-bedded. Outcrop 1.3 mi. E. of Bolivar	28.86	18.81	39.5	2.05	.10		do.	3.56

position is a stratigraphic feature, and that the mineral dolomite is of sedimentary or diagenetic origin. On the other hand, the lower beds are exposed only in the easterly outcrops, and the effects of metamorphism are increasingly apparent eastward, as described on pages 35-36. It might be inferred, therefore, that all the carbonate rocks were originally limestone, that magnesia was introduced during recrystallization, and that the more easterly rocks were more uniformly converted to dolomite than were those farther west. The analyses alone will support either inference, and geologic literature contains well-substantiated examples of both types of origin.

It is clear at least that the origin of the dolomite is not related to the deposition of ore minerals, for the content of magnesia shows no areal relation to the mineral deposits, and carbonate rocks exposed in and near mine openings are identical with those elsewhere. The carbonate rocks in the Weisner formation, which are described above, are similar in appearance to those in the Rome formation, but they occur farther east, and they contain quite uneven proportions of calcite and dolomite, as shown by tests with hydrochloric acid. Still farther east, in an environment of stronger metamorphism, Bayley[21] found that the rocks called the Murphy marble also contain widely different proportions of dolomite, and that high-calcium and low-calcium rocks are separated only by sharp bedding planes. It appears, therefore, that the rock-forming dolomite in the Cartersville district and adjacent region was not formed by solutions related to metamorphism. It is believed to be of premetamorphic origin, but there is no evidence to indicate whether it was precipitated directly in beds or was formed by reaction between limestone and sea water.

Fossils have been found, at two localities in the northern part of the district, in beds of the weathered carbonate rocks immediately adjacent to the overlying metashale of the Conasauga formation. Butts[22] collected the following forms one mile southwest of Rydal, on the banks of Little Pine Log Creek:

Alokistokarella sp.
Ehmaniella sp.
Elrathiella sp.
Solenopleura sp.

In a cut of the Louisville and Nashville Railroad, 0.7 mile north of Rydal, the writer collected the incomplete remains of two trilobites that, though indeterminable, are undistorted, although shaly laminae in the enclosing limestone have been recrystallized to fine-grained muscovite.

It is evident, therefore, that recrystallization did not involve appreciable shearing. Billings and Sharp[23] have shown that much stronger metamorphism does not necessarily obliterate fossils. They describe a *Spirifer*, not greatly distorted, that is preserved in a silicate schist with tectonite texture.

[21] Bayley, W. S., Geology of the Tate quadrangle, Georgia: Georgia Geol. Survey Bull. 43, pp. 80, 91, 157-158, 1928.

[22] Butts, Charles, personal communication.

[23] Billings, M. P. and Sharp, R. P., Petrofabric study of a fossiliferous schist, Mt. Clough, New Hampshire: Am. Jour. Sci., 5th ser., vol. 34, pp. 277-292, 1937.

STRATIGRAPHIC RELATIONS AND THICKNESS

The carbonate rocks of the Rome rest on the Shady formation where it is present and on the Weisner formation where the Shady is not present. The actual contacts between the carbonate and underlying rocks are nowhere exposed, owing to the obscuring effects of chemical weathering, but they are believed to be conformable, as beds in the different formations are parallel in adjacent outcrops.

The carbonate rocks make up the lower part of the Rome formation in the ridge belt, in parts of which their relation to the Weisner formation and the metashale of the Rome formation are well exposed. The thickness of the carbonate rocks in that area ranges from about 25 to 400 feet. They taper out eastward but thicken westward and probably reach a thickness of at least 1,800 feet in the area west of the ridge belt. Even in the western part of the ridge belt, however, the carbonate rocks are absent in places and metashale of the Rome formation immediately overlies the Weisner formation, particularly in the areas southeast of White and north of Pine Log Mountain. (See the geologic map, pl. 1, and description of the Boneyard mine.) In and to the east of the ridge belt, the carbonate rocks occur at the base of the metashale only in isolated, lenticular bodies. The relation of the carbonate rocks and the metashale is discussed further on pp. 15-16.

The parts of the carbonate rocks, west of the ridge belt, which are in contact with rocks mapped herein as Shady and as Weisner, have been called the Beaver limestone by Hayes[24], and the Shady limestone or dolomite by all later workers. The writer also has previously called the carbonate rocks the Shady dolomite[25], including with them the hematite beds to which the name Shady is restricted in the present report; the common usage was followed to avoid misunderstanding.

The correlation of the carbonate rocks involves a sharp contrast between their lower and upper contacts. The fossiliferous rocks of the Shady formation are not everywhere overlain by the carbonate rocks, and the carbonate rocks are not everywhere underlain by these hematite beds. In most of the western part of the district, however, the carbonate rocks conformably overlie the Shady rocks where the latter are present, and those of the Weisner formation where the Shady is absent; the lower contact of the carbonate rocks, therefore, is nearly everywhere well defined.

In contrast, there is no well-defined upper contact. The carbonate rocks grade upward and laterally into calcareous metashale, and their thickness is very uneven. (See pl. 5.) The deposition of the carbonate rocks, therefore, must have been very closely related, in time and environment, to that of the metashale, and they are correlated together herein as members of one formation.

METASHALE

DISTRIBUTION

The metashale member of the Rome formation overlies the carbonate rocks in and along the western side of the ridge belt. The carbonate rocks taper out eastward; the metashale thickens correspondingly and constitutes nearly all of the formation in the eastern part of the district. In and west of the ridge belt the metashale is rather thin and calcareous, and the carbonate minerals have been deeply leached in the zone of weathering. The leached rock is not resistant to erosion; the metashale in those areas therefore underlies parts of the valleys and lower slopes. The metashale is mostly noncalcareous where carbonate rocks do not constitute the lower part of the formation. The noncalcareous metashale is relatively resistant to erosion, and underlies a considerable part of the Piedmont upland in the southeastern part of the district.

LITHOLOGY AND FAUNA

Normal facies.—Most of the metashale in the Rome formation, like that in the Weisner formation, consists almost entirely of fine-grained muscovite oriented parallel to the bedding. Minor amounts of fine-grained quartz, orthoclase or microcline, and sodic plagioclase are sporadically present. The fresh rock is bluish gray to greenish gray, but random beds are dark gray to black because of finely disseminated graphite. Most of the rock in the outcrops is strongly weathered, but retains its sharply bedded structure. The weathered calcareous metashale is soft and mealy, and contains abundant micaceous laminae; most of it is light yellow, but some beds are pink, purple, brown, and light gray to black. The weathered noncalcareous metashale is brittle, uniformly micaceous, and brownish gray in color.

The calcareous parts of the metashale in places contain lenticular bodies of crystalline dolomite and limestone. The lenticular bodies that have been found in mapping are shown, in plate 1, in the extreme northeastern and southeastern parts of the district. It is likely that there are many more of these bodies and that their outcrops are obscured by weathering. Most of the carbonate rocks are light to dark bluish gray, but white dolomite occurs in the bodies shown 1 mile north of Oak Hill Church, and 0.6 mile southwest of the Kelly mine. The Rome trilobite, *Solenopleura virginica,* has been found by G. W. Crickmay

[24] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, pp. 404-406, 1901.

[25] Kesler, Thomas L., Sienna ("ocher") deposits of the Cartersville district, Georgia: Econ. Geology, vol. 34, pp. 324-341, 1939; Structure and ore deposition at Cartersville, Georgia: Am. Inst. Min. Met. Eng., Tech. Pub. no. 1226, pp. 1-17, 1940.

in weathered beds of the lenticular body of carbonate rocks shown 1.5 miles east of Bolivar.[26]

The metashale contains a few sporadic beds of quartzite like that in the Weisner formation except that the beds are mostly thin. These quartzite beds in the metashale are exposed at the Barium Reduction and Dobbins mines and in a road cut 2.5 miles north of Cartersville immediately west of the Louisville and Nashville railroad. Pseudo-*Scolithus* tubes, identical in all respects with those in the Weisner formation, described on page 10, occur in thin beds of the quartzite, near the base of the metashale, on a hill one mile northeast of Cartersville.

The metashale also contains thin and thick beds of metasiltstone identical with that which is so abundant in the Conasauga formation. The rock is described in detail appropriately in the section on the Conasauga formation. (See pages 18 to 19.) The metasiltstone, like the quartzite, occurs very irregularly in the metashale but is more common. In the western part of the district, beds of metasiltstone in the metashale are well exposed at the Bell mine and in railroad and highway cuts south of Aubrey Lake. In the eastern part they are abundant and well exposed in the area along the Etowah River northeast of the Iron Hill mine and both at Campbell Hill and northwest of that place.

Chloritic facies.—Irregular parts of the metashale of the Rome formation are weakly chloritic. The largest of these parts occur in the northeastern and southern parts of the district, where outcrops are adequate for delimiting them. The chloritic rock has been identified at other places, however, where it cannot be delimited owing to the scarcity of outcrops. The principal bodies of the rock are shown in plate 1, but isolated outcrops also occur on the Etowah River, 0.7 mile below Island Mill Bend and 0.8 mile northwest of the Paga No. 1 mine, along a country road 1.8 miles due west of Payne, and in a railroad cut 1.2 miles southwest of Allatoona.

The chloritic metashale is light gray, and has a faint greenish cast by which it can be recognized in the field if not too deeply weathered. It is so fine-grained that the constituent minerals can be recognized and distinguished only under the microscope. The principal constituent is fine-grained colorless muscovite with which is intergrown, in by far the greater part of the rock, a small and irregular amount of pale-green optically positive chlorite. Local and irregular parts of the rock contain, instead of the chlorite, a small amount of a micaceous mineral that is either iron-rich muscovite or biotite, for its interference colors indicate a birefringence similar to that of the micas, the optic sign is negative, and the color is brownish-green of much greater strength than the pale-green color of the more common chlorite. The common orientation of all the micaceous minerals gives the metashale a foliation which is parallel to sporadic beds of slightly chloritic metasiltstone and white to light-gray dolomite.

The more common interstitial accessory minerals are fine-grained calcite, quartz, and sodic plagioclase. The calcite in the fresh rock invariably effervesces more vigorously in hydrochloric acid than does the carbonate in the nonchloritic metashale. Less common accessory minerals include fine-grained epidote, brownish-green biotite, tourmaline, and apatite. Pods of vein quartz occur irregularly in the rock, and in places they contain small clusters of chlorite. In a few places where the rock contains an unusually large amount of calcite the outcrops have been made cavernous by weathering.

The metasiltstone referred to above occurs in sporadic thin and thick beds. It has the same mineral composition as the chloritic metashale with which it is interbedded, except that the granular minerals are much more abundant than the micaceous minerals. The dolomite occurs in thin, sharply defined, lenticular beds conformable in the chloritic metashale on the southwest side of Pumpkinvine Creek. Its relation to the metashale is clearly exposed at the mouth of a small tributary 0.8 mile due west of the Kelly mine, and it also crops out 0.2 mile farther southwest in the bed of the same tributary.

As the descriptions indicate, the mineral composition and structure of the chloritic metashale differ from those of the nonchloritic rock only in the presence of a small amount of chlorite and the less common accessory minerals, and in the apparent absence of magnesium carbonate.

STRATIGRAPHIC RELATIONS AND THICKNESS

Metashale of the Rome formation clearly overlies the carbonate rocks wherever the two members together constitute the formation. The carbonate rocks directly underlie the Conasauga formation only where the metashale is absent, in the western part of the district. Similarly, the metashale directly overlies the Shady and Weisner formations only where the carbonate rocks are absent, in the ridge belt and the eastern part of the district. The two members occur, therefore, as complementary wedges, and structure sections plotted from outcrops (see pl. 1) show that the total thickness of the formation is at least 2,000 feet, regardless of the local thickness of either member.

The metashale is about 600 feet thick at its westernmost occurrence as a continuous series, in the synclinal body that underlies an area west of and parallel to the ridge belt. The thickness of the series increases, however, to the southwest, northeast, and southeast. In the area directly west of Cartersville

[26] Butts, Charles, personal communication.

the metashale is unusually calcareous and is overlain directly by Knox dolomite 2 miles west of the town. In the valley of Pine Log Creek, the metashale is about 1,100 feet thick, and is overlain conformably by the Conasauga formation. In the area east of the ridge belt, the metashale makes up all of the Rome with the exception of a large lenticular body of the carbonate rocks, which underlies an area that contains the Iron Hill mine.

It is in the ridge belt, therefore ,that the carbonate rocks taper out eastward as a continuous series. The transition is not uniform, however, as shown by differences in the stratigraphic sections exposed in the walls of open-cut mines, most of which are in the ridge belt. Columnar sections illustrating the uneven stratigraphy of the lower part of the Rome formation are shown in plate 5. The sections are arranged in groups that in general reflect variations across the strike. They illustrate the nonuniform relation of the carbonate rocks and metashale, the uneven occurrence of the Shady formation, and the general eastward thinning of the carbonate rocks.

The differences in the thickness of the carbonate rocks is particularly important, for the clays residual from the weathering of those rocks contain most of the deposits of barite, manganese, and brown iron ore. Further, the highly uneven thickness of the carbonate rocks appears to be unique, for these rocks correspond to the Shady dolomite of other Appalachian areas where no such variation has been reported.

In the ridge belt, the uneven transition between the carbonate rocks and the metashale of the Rome formation results in the irregular contacts shown on the geologic map. These contacts are difficult to trace, and, though clearly exposed in many open-cuts, are commonly concealed in the intervening areas by a surficial mantle of colluvium. (See pp. 24-25.) As a result of the uneven thickness of the carbonate rocks, there is a marked variation in the width of the areas they underlie, without any apparent change in their dip. Hence, contacts are not even and parallel in all parts of the ridge belt.

The metashale is variably calcareous wherever it is underlain by the carbonate rocks, and hence its susceptibility to weathering in the ridge belt and the western part of the district. This feature, together with the highly uneven thickness of the two members in the ridge belt, suggests that the carbonate rocks and the metashale intergrade. The occurrence of lenticular bodies of carbonate rocks in the metashale is further evidence of intergradation. Equivalent age is shown by the presence of *Solenopleura*, as described above, in the upper part of the carbonate member and in a lens of carbonate rocks at about the same stratigraphic level in the metashale.

Evidence that the nonchloritic metashale grades into the chloritic metashale is more conclusive. North of Pine Log Creek, the chloritic metashale conformably underlies the Conasauga formation. Due east of Bolivar, it overlies the nonchloritic metashale, but its lower limit is irregular and this feature becomes more pronounced eastward. The chloritic metashale correspondingly increases in thickness eastward, until, 1.7 miles east of Oak Hill Church, it conformably overlies the Weisner formation and occupies the stratigraphic interval occupied by the nonchloritic metashale and carbonate rocks farther west. The contact between the chloritic and underlying nonchloritic metashales is not sharply defined. The chloritic rock can be identified only in relatively unweathered outcrops, for, when deeply leached, the rock is indistinguishable from the more coarse-textured parts of the nonchloritic metashale. For this reason, the rock is probably more common than is indicated by the weathered outcrops that characterize the region.

The chloritic metashale in the southern part of the district has no such well-defined stratigraphic position. South of Pumpkinvine Creek, it overlies the nonchloritic, calcareous metashale, and the contacts here also are quite indefinite. Along United States Highway No. 41, it is exposed in two narrow bodies interbedded with the nonchloritic metashale. The rocks northeast of the highway are deeply leached, and the normal and chloritic facies of the metashale cannot easily be differentiated. The chloritic rock is well exposed in the deep railroad cut at Allatoona where it is bounded on the southeast by a body of oligoclase-mica gneiss. The metashale here contains the less common accessory minerals listed above.

The chloritic metashale, therefore occurs with and in places is stratigraphically equivalent to calcareous nonchloritic metashale. The small amount of chlorite is believed to have been developed during the recrystallization of the rocks with magnesia supplied by disseminated dolomite, leaving calcite as a characteristic residual carbonate mineral.

AMPHIBOLITE

DISTRIBUTION

Considerable areas in the southeastern part of the district are underlain by amphibolite. These areas are somewhat irregular in outline but are in general thinly elliptical. They are irregular also in size and are surrounded by areas underlain by metashale of the Rome formation and by feldspathic gneiss. The amphibolite is more resistant to weathering than the other rocks and is covered with a thin red to olive-brown rocky soil.

LITHOLOGY AND PHYSICAL RELATIONS

The amphibolite is dark green, fine- to medium-grained, and sharply layered. The most abundant mineral is green hornblende, which occurs in prisms oriented parallel to the layers. Interlocking, anhedral grains of quartz and plagioclase occur interstitially in various proportions. The plagioclase in specimens from five localities is very sparsely twinned, and its composition ranges from An_5 to An_{23}. Sporadically present are epidote and a carbonate mineral that locally constitutes as much as 30 percent of the rock. Garnet occurs in abundant euhedral crystals in the small body of amphibolite 0.5 mile southwest of Payne but has not been observed in the rock elsewhere. None of the minerals are deformed. In the area northwest of Payne the amphibolite is cut by thin white veins, mostly less than 2 inches thick, consisting of coarse-grained oligoclase and smaller amounts of rutile and sphene.

The layers of the amphibolite are conformable with and as sharply defined as the beds of metasediments in the Rome formation in the adjacent area. Contacts between the amphibolite and the other rocks are locally well exposed, and in none of the exposures does the amphibolite cut across the structure of the other rocks. The amphibolite is sharply interbedded with metashale of the Rome in a large exposure along United States Highway No. 41, 1.5 miles southwest of Allatoona. There, the beds of both rocks occur together in isoclinal folds, some of which are sliced by minor thrust faults. The exposure shows clearly that the rocks from which the amphibolite and the metashale were derived were interbedded prior to folding.

The zigzag contacts shown on the geologic map are drawn where the amphibolite and the other rocks appear to intergrade without change in the attitude of beds and layers. These contacts between the amphibolite and the metashale are probably due both to interfingering of beds and to folding, but the relative importance of these factors cannot be determined owing to the lack of continuous exposures along the strike. The zigzag contacts between the amphibolite and the gneiss represent a transition resulting from the process of replacement described on page 39.

CORRELATION

Amphibolite is commonly interpreted as metamorphosed mafic rock of igneous or related pyroclastic origin, or as metamorphosed carbonate rock of sedimentary origin.

There are no mafic rocks of proved igneous or pyroclastic origin in the Cartersville district or in the adjacent region shown in figure 4. The district contains much crystalline dolomite and limestone in the Rome formation, however, and the occurrence of the carbonate rocks is similar to that of the amphibolite. Both are sharply bedded and in places are interbedded with metashale, and in places the carbonate rocks, like the amphibolite, occur in lenticular bodies. Thin sections show no evidence that the carbonate which some of the amphibolite contains could have been formed by the alteration of the hornblende, for the texture of the hornblende is uniform regardless of the presence or absence of calcite.

Marble and crystalline dolomite and limestone are known at many places in northern Georgia.[27] Many of the outcrops of the carbonate rocks are obscure owing to deep weathering, and these rocks probably are more common than is supposed. The published descriptions show that tremolite, phlogopite, quartz, and feldspar are common products of metamorphism in these rocks. Hornblende of similar origin, though less commonly reported, is also present in places.[28] The only detailed study of any of these carbonate rocks has been made in the Tate quadrangle by Bayley, who states that the Murphy marble in that area contains "many other streaks and vein-like masses" of hornblendic rock, and that these "may be portions of the marble or of other calcareous sediments that have been metamorphosed".[29] The writer[30] has shown that crystalline carbonate rocks in the Carolinas contain unevenly distributed silicate minerals of metamorphic origin and grade into sharply layered hornblende gneiss composed entirely of these silicate minerals.

There is some evidence, therefore, that the amphibolite of the Cartersville district may be metamorphosed carbonate rock of sedimentary origin. There is no evidence that it is metamorphosed igneous rock. Accordingly, the amphibolite is correlated with the carbonate rocks of the Rome formation, for, like them, it is closely associated and even interbedded with metashale of the Rome, and its continuity and thickness are not uniform. The correlation accords with the distribution of amphibolite and carbonate rocks in a major synclinorium described on pages 33-35.

CONASAUGA FORMATION (MIDDLE AND UPPER CAMBRIAN)

DISTRIBUTION

The Conasauga formation overlies the Rome formation, and its rocks are more resistant to weathering than those of the Rome. As the top of the Rome formation is exposed only in the northern part of

[27] McCallie, S. W., A preliminary report on the marbles of Georgia: Georgia Geol. Survey Bull. 1, 2d ed., pp. 35-72, 1907.

Maynard, T. P., A report on the limestones and cement materials of North Georgia: Georgia Geol. Survey Bull. 27, pp. 115-128, 1912.

LaForge, Laurence and Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Ellijay folio (no. 187), pp. 52-54, geologic map, 1913.

Bayley, W. S., Geology of the Tate quadrangle, Georgia: Georgia Geol. Survey Bull. 43, pp. 75-102, 146-159, geologic map, 1928.

[28] McCallie, S. W., op. cit., pp. 39-40. LaForge, Laurence and Phalen, W. C., op. cit., p. 112. Bayley, W. S., op. cit., p. 89.

[29] Bayley, W. S., op. cit., p. 28.

[30] Kesler, T. L., Correlation of some metamorphic rocks in the central Carolina Piedmont: Geol. Soc. America Bull., vol. 55, pp. 755-782, 1944.

the district, the Conasauga rocks underlie the higher ground in that area. They crop out principally on low ridges between Bolivar and the vicinity of Aubrey Lake, and on the Piedmont upland in the extreme northeast corner of the district.

LITHOLOGY

The Conasauga formation is similar to the Weisner formation in that it consists largely of noncalcareous metashale, which is unevenly graphitic in places and contains thin and thick beds of more competent rocks. These competent beds include a little quartzite and impure crystalline dolomite, and much metasiltstone that characterizes the formation.

Sporadic beds of the quartzite crop out near the position of cross-section line B–B′ (plate 1) on the hill 0.4 mile northeast of Oak Hill Church, and 1 mile farther northeast on Johnson Mountain. Sporadic beds of the dolomite crop out on the hill northeast of Oak Hill Church, on another immediately northeast of White, and on a third 0.5 mile due west of Aubrey Dam.

The metashale, quartzite, and dolomite are similar to those in the other formations previously described. Although metasiltstone is a minor and irregular constituent of both the Wëisner formation and the metashale of the Rome formation, it is abundant in the Conasauga formation. The rock is therefore described in this section of the report, but the description applies equally to the metasiltstone in the Weisner and Rome formations.

In the ridges west of the Louisville & Nashville railroad both the metasiltstone and the metashale with which it is interbedded are very fine-grained. The metasiltstone is the more resistant to weathering; it crops out more boldly than the metashale, and weathered slabs of it persist as float even where there are no outcrops. The only exposure of fresh rock, however, is at the dam of Aubrey Lake. (See pl. 4*B*.) The unweathered metasiltstone is white to light gray and has a dense, hornfelslike texture. The beds at the dam and elsewhere are unlaminated to weakly laminated and range in thickness from less than an inch to 18 inches or more. The fresh rock is very hard, and cannot be scratched with a knife. It effervesces in dilute hydrochloric acid, slightly if unpowdered, rather vigorously if powdered. In thin section the rock is seen to consist principally of very fine-grained quartz, microline or orthoclase, sodic plagioclase, carbonate, and a little muscovite, which is mostly interstitial but which also forms short laminae. Tourmaline and zircon are present sparsely in minute grains. Thin sections of samples collected at different localities show considerable variation in the proportions of these minerals, particularly the carbonate minerals. The mineral grains are anhedral and interlocking, and none of them show any evidence of abrasion or weathering. (See pl. 4*C*, *D*.)

Weathering removes the finely disseminated carbonate minerals, and gives the rock a finely porous texture and gritty feel. These features led Shearer[31] to call the rock feldspathic sandstone. The mineral grains have sutured contacts, however, and most of them are somewhat less than 1/16 millimeter thick, which, in the clastic sediments, characterizes siltstone rather than sandstone.[32] The chemical composition of the rock also resembles that of silt, as shown in table 2, but the rocks from which the samples were obtained are mildly weathered, and the analyses do not reflect the usually appreciable amounts of carbonate minerals. As these have been leached, the amounts of MgO and CaO shown are low, and those of the other constituents are somewhat high.

TABLE 2.—*Principal chemical constituents of metasilststone and Recent silt*

	Metasiltstone in the Cartersville district[1] (percent of constituents in indicated sample)						Recent silt[4]
	[2]1	[3]2	[3]3	[3]4	[3]5	Average	
SiO_2	68.40	78.42	80.00	78.38	73.10	75.66	69.96
Al_2O_3	14.44	10.52	11.04	8.98	10.26	11.05	10.52
Fe_2O_3	3.58	1.24	1.92	3.30	4.98	3.00	3.47
FeO	.56	----	----	----	----	----	----
MgO	.20	.12	.45	.14	.16	.21	1.41
CaO	.00	.00	tr.	tr.	.00	----	2.17
Na_2O	.47	1.36	.24	2.73	1.42	1.24	1.51
K_2O	7.77	5.90	2.45	4.54	8.22	5.78	2.30
TiO_2	.96	.72	.96	.72	.72	.82	.54
CO_2	----	----	----	----	----	----	1.40

[1]The rocks are mildly weathered, and the amounts of MgO and CaO are low owing to the loss of carbonate minerals.

[2]Shearer, H. K., Report on the slate deposits of Georgia: Georgia Geol. Survey Bull. 34, p. 151, 1918.

[3]Hazeltine, R. H., Notes on rocks occurring in the Cartersville slate (manuscript report in files of Georgia Geol. Survey).

[4]From Clarke, F. W., and Steiger, George, The relative abundance of several metallic elements: Wash. Acad. Sci. Jour., vol. 4, p. 59, 1914.

That the rock is recrystallized is indicated by its texture and by its occurrence in recrystallized shales. As its composition and grain size correspond approx-

[31] Shearer, H. K., Report on the slate deposits of Georgia: Georgia Geol. Survey Bull. 34, p. 130, 1918.

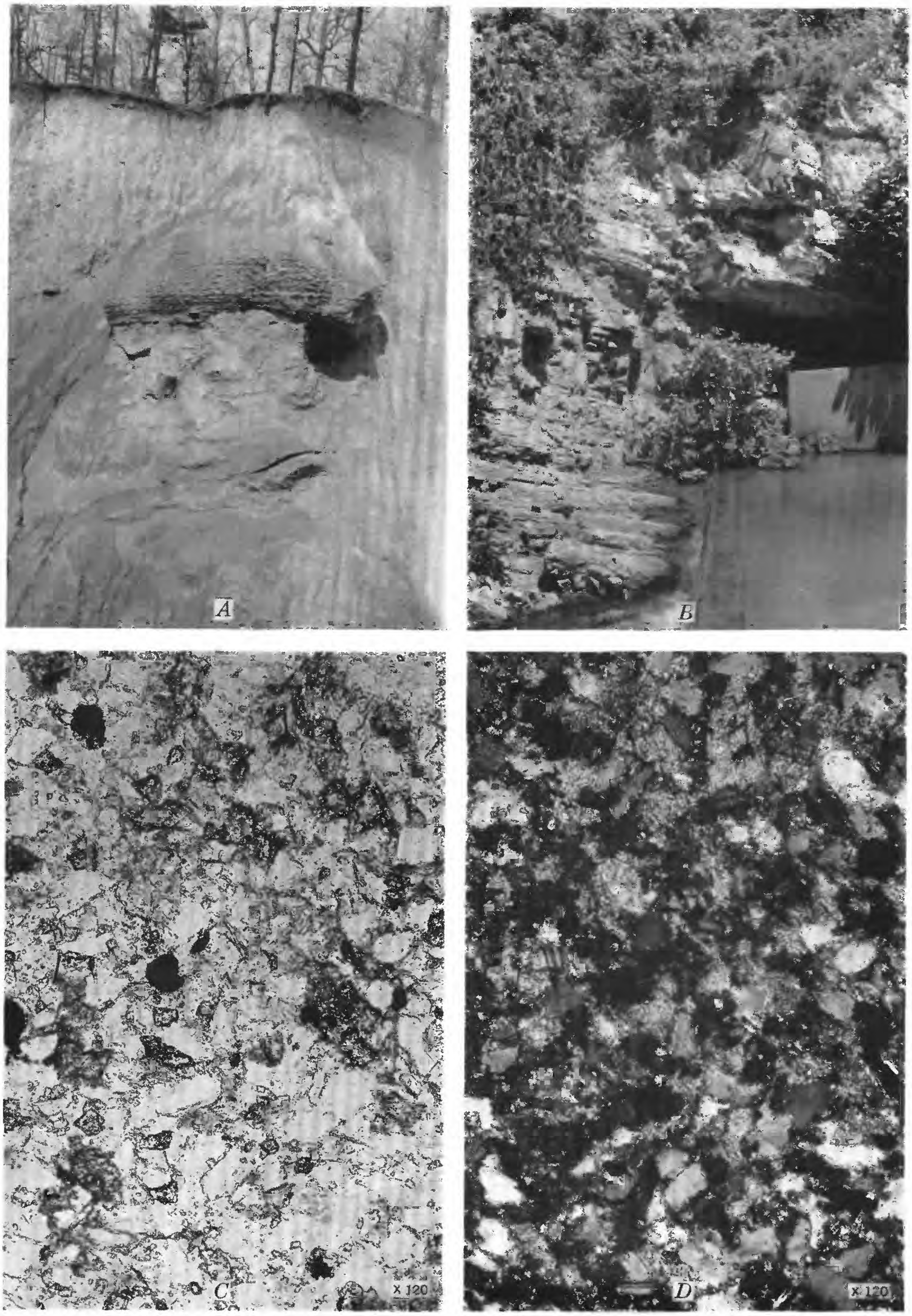
[32] Twenhofel, W. H., Principals of sedimentation, 1st ed., pp. 270, 293, 1939.

EXPLANATION OF PLATE 4

A, Dolomite of the Rome formation containing thin beds of metashale that are resistant to weathering. Exposure in the Paga No. 1 mine.

B, Exposure of metasiltstone of the Conasauga formation at Aubrey Dam.

C, *D*, Photomicrographs of metasiltstone from the vicinity of Aubrey Dam. *C*, With plain light, showing abundance of dolomite—the mineral with various degrees of high relief—and scarcity of muscovite—the lamellar material. *D*, With crossed nicols, showing interlocking relation of quartz and feldspars; note twinning in some feldspar grains.


A
B
C
× 120
D
× 120

imately with those of siltstone, the rock is classed as metasiltstone. All of the characteristics described, except grain size, apply to the metasiltstone throughout the district. The grain size increases eastward and southward, as does that of the minerals in the rocks associated with the metasiltstone. The coarsest texture of the rock occurs in the Conasauga formation in the extreme northeast corner of the district, and in the Rome formation in the areas mentioned on page 15. It has the appearance of very impure quartzite or fine-grained arkose, and the surface is characterized by white to light-brown slabs weathered from the beds. Some of the beds contain megascopic grains of quartz and feldspar; these are apparently detrital because they are rounded, unlike the finer, sutured grains of the groundmass.

STRATIGRAPHIC RELATIONS AND THICKNESS

The Conasauga formation overlies the Rome formation, and the beds of the two formations are conformable in all outcrops at and near the contact. Owing to the thinning out of the metashale member of the Rome formation westward, the Conasauga overlies the carbonate rocks of the Rome in nearly all of the northwest part of the district, but in the area south of Aubrey Lake the Conasauga overlies the westernmost part of the metashale of the Rome. The Conasauga and part of the Rome have been removed by erosion between this area and the valley of Pine Log Creek, but the metashale thickens in this interval, becoming chloritic. Hence, on the slope north of Pine Log Creek, the Conasauga formation directly overlies the metashale; the beds are parallel, and occur in minor undulatory folds. The rocks in this area are well exposed in many ravines. They have been mapped with considerable care (see pl. 1), and their attitudes reflect an undoubtedly conformable relation between the formations.

Shearer[33] has grouped together some parts of the Conasauga and Rome formations in which metasiltstone is common, and has designated them as the Cartersville formation. It has been impossible to adhere to this grouping in the present work, for Shearer's contacts transgress the strike of the rocks, and his formation includes carbonate rocks, calcareous metashale, and noncalcareous metashale which, as shown herein, are stratigraphically distinct.

Owing to the abundance of microcline and muscovite in the metasiltstone and associated metashale, some of the rocks in Shearer's group have been prospected as possible sources of potash.[34] These attempts at development did not mature, and the rocks appear to be no more a commercial source of potash than any other silicate rocks containing the same minerals.

No fossils have been found in the Conasauga rocks in the district, although the fossils that have been found in the Rome formation occur very near the contact. The Conasauga is correlated entirely on its sharp contact with and lithologic distinction from the Rome, and on superposition.

The thickness of the formation is unknown, as the top is not exposed, but the part of it that underlies the upland north of Pine Log Creek is at least 2,000 feet thick.

GNEISSES DERIVED FROM CAMBRIAN ROCKS

GENERAL FEATURES

Much of the central, eastern, and southeastern parts of the district are underlain by medium- to coarse-grained feldspathic gneisses that contain large amounts of bluish quartz. They range in color from white to dark greenish gray. As shown on the geologic map, there are three varieties of the gneisses, and they are distinct in appearance.

One variety, here called oligoclase-mica gneiss, is white to light brownish gray, and consists largely of oligoclase, quartz, and laminae of mica, with widely different proportions of orthoclase; the mica laminae are parallel, and give the rock a pronounced foliation. Another variety, called andesine-augite gneiss, is dark greenish gray, and consists largely of andesine with smaller amounts of quartz, biotite, partly uralitized augite, and a little orthoclase irregularly distributed; the minerals have no common orientation, but the rock is sharply layered. The third variety, a porphyroblastic gneiss, is characterized by abundant large crystals of orthoclase enclosed in a groundmass that in some places has the mineral composition and structure of the oligoclase-mica gneiss, and in other places those of the andesine-augite gneiss. Accordingly, the appearance of the rock is not uniform; it is foliated and light in color where mica laminae are present, and layered and darker where mica laminae are not present, but the foliated structure is the more common.

Much of the potash feldspar in the gneisses irregularly contains patchy or incompletely developed microcline twinning. The indices of refraction of many specimens of the feldspar, as determined in immersion media, are low (α about 1.517), and are essentially the same in grains that contain the twinning and those that do not contain it. The twinning appears to be of secondary origin (see p. 20), and for convenience the potash feldspar as a whole will be called orthoclase.

The mutual relations of the gneisses are obscure as a result of deep weathering, but it is believed that the rocks intergrade. This belief is based on the occurrence of sparsely disseminated orthoclase prophyroblasts in both the oligoclase-mica gneiss and

[33] Shearer, H. K., op. cit., pp. 128-132, map III, 1918.

[34] Shearer, H. K., op. cit., pp. 132-163.

the anedsine-augite gneiss, near contacts with the porphyroblastic gneiss. This feature, together with the irregular character of the groundmass of the porphyroblastic gneiss, suggests that the porphyroblasts merely mask a complex association of the two nonporphyroblastic gneisses.

Contact relations show that the gneisses are younger than the enclosing metasediments, and were therefore developed in post-Cambrian time. All evidence obtained in the present work indicates that the gneisses were formed by the alteration through igneous influence of large parts of the older rocks after most of the folding had occurred. This evidence is discussed farther on in the report. (See pp. 38-45.) The only post-Cambrian time in which this alteration might have occurred is the late Carboniferous, which coincides with the time of folding. (See p. 27.) The gneisses are therefore believed to have been developed in late Carboniferous time.

OLIGOCLASE-MICA GNEISS

FIELD DESCRIPTION

Bcause of its color and texture the oligoclase-mica gneiss is of the general variety commonly referred to as granitic gneiss. The rock is white to medium gray and medium- to coarse-grained. The coarsest-grained and most abundant constituents are feldspar and bluish quartz. The feldspar crystals are in general one-fourth inch or less in length. Muscovite, with or without biotite, occurs in short parallel laminae, and the abundance and thickness of the laminae give the gneiss weak to strong foliation. Locally, near contacts with amphibolite, the gneiss contains hornblende rather than mica laminae, as described on page 39.

A layered structure, parallel to the foliation, is apparent in a few places, but the occurrences are too uncommon to serve as a basis for structural mapping. The layered structure is marked both by sharply defined differences in the proportion of micas to other minerals and by very thin and persistent films of mica in rock of homogeneous composition and texture.

MICROSCOPIC FEATURES

Thin sections of the oligoclase-mica gneiss show that plagioclase, of composition An_{10} to An_{15}, is the dominant feldspar. Orthoclase with sporadic microcline twinning is commonly though not everywhere present, in widely varying proportions; it appears to be most abundant in the body of the gneiss shown on the map in the middle of the eastern border of the district. The relative proportions of the feldspars cannot be used as a basis for areal mapping, owing to the irregular occurrence of the orthoclase. The more common variety of the rock, in which orthoclase is a minor constituent, will be described first.

The principal constituents of the rock are oligoclase and quartz, with the latter somewhat the more plentiful. They occur in irregular grains with sutured contacts. The quartz shows mild undulatory extinction, but is not crushed. The oligoclase, which also is uncrushed, shows sporatic albite twinning. Much of it is clouded with fine-grained inclusions, as shown in plate 6*A*, *B*. In most of the gneiss these inclusions are very fine-grained muscovite, which in some grains are oriented in trends[35] and in others are unoriented. Even in the same thin section, the inclusions are limited to the cores of some feldspar grains but occur throughout other grains. Twinning, if present, may be limited to the clouded core of a grain (pl. 6*A*), or may characterize the entire grain. In some thin sections the inclusions consist of clinozoisite in addition to muscovite; in other sections they consist entirely of clinozoisite.

The most plentiful of the minor constituents are muscovite and greenish-brown biotite, which occur in parallel laminae and also in isolated plates. Muscovite is usually the more abundant, but in one thin section the proportion is reversed; a little of the biotite in this section is altered to chlorite. Some of the mica plates curve around feldspar grains, but others abut sharply against them; both relations are shown in plate 6 *A*, *B*. Orthoclase is sparsely present in anhedral grains embayed by the quartz. Calcite occurs unevenly, in ragged grains, with the feldspars and quartz, and in very fine-grained aggregates in the mica folia. (See pl. 6*A*.) Fine-grained clinozoisite is abundant in some thin sections but absent in others. The other accessory minerals include apatite, pyrite, sphene, and garnet, all fine-grained. These minerals are very scarce.

In some parts of the gneiss, particularly in outcrops east of Stamp Creek and south of Payne, the potash feldspar is a prominent or even dominant constituent. It occurs in large anhedral crystals containing irregularly distributed blebs and spindles of sodic plagioclase. The potash feldspar is mildly fractured in most of the gneiss, but is locally more strongly fractured. Rather indistinct microcline twinning occurs in the crystals; it is unevenly distributed, and its prominence is in direct proportion to the extent of fracturing. This relation between rupture and twinning is consistent in the other gneisses, and in the Cambrian metasediments as well. (See pp. 21, 23, 41.) The twinning is therefore interpreted as an indication of strain, which Alling[36] believes it to be.

Most of the matrix consists of oligoclase and quartz, in various proportions. The oligoclase is

[35] Ingerson, F. E., Albite trends in some rocks of the Piedmont: Am. Jour. Sci., 5th ser., vol. 35-A, pp. 127-141, 1938.

[36] Alling, H. L., The mineralography of the feldspars: Jour. Geology, vol. 29, pp. 206-210, 275-276, 1921.

finer-grained than the orthoclase, embays the orthoclase, and is fractured wherever the orthoclase is fractured. Some of the grains contain myrmekitic intergrowths of quartz, but this feature is not evident in all thin sections. The quartz fills fractures in the orthoclase, but not in the oligoclase, which indicates that the oligoclase is the younger. The quartz shows strain shadows wherever the feldspars are fractured. The mica laminae are in some places relatively thick and continuous and are alternate with layers of the granular minerals. A photomicrograph of strongly foliated gneiss containing the maximum proportion of potash feldspar is shown in plate 6*C*. The granular layers consist of coarse-grained orthoclase and a smaller amount of fine-grained oligoclase, both of which have been weakly strained and fractured. The orthoclase is cut by veinlets of quartz, which also occurs in irregular lenses; the quartz has strain shadows oriented parallel to the mica laminae.

ANDESINE-AUGITE GNEISS

FIELD DESCRIPTION

The andesine-augite gneiss occurs in relatively small bodies enclosed in the porphyroblastic gneiss, and it is commonly associated with bodies of the Cambrian rocks that are similarly enclosed. The rock is dark greenish gray, medium-grained, and even-textured, and hand specimens of it closely resemble a massive igneous rock. (See pl. 7*A*.) The hand lens shows the rock to consist mostly of feldspar. Smaller amounts of bluish quartz, biotite, and disseminated metallic minerals also are evident in hand specimens. Field tests with hydrochloric acid have shown that the gneiss in many but not all outcrops contains evenly disseminated calcite.

Even in the outcrops it can be seen that the minerals are more or less equidimensional and that the plates of biotite have no common orientation except in rare and discontinuous laminae. The rock consequently lacks the foliate structure that characterizes the oligoclase-mica gneiss, but it is sharply divided into layers, mostly from 2 inches to 2 feet thick, and therefore has a gneissic structure. (See pl. 7*B*). These layers are invariably parallel to the folation of adjacent porphyroblastic gneiss and to the bedding of adjacent Cambrian rocks. Contact relations with these rocks are obscure, however, for the andesine-augite gneiss weathers readily to a thin red soil in which residual boulders are plentiful. The boulders are fresh with the exception of a thin weathered selvage.

MICROSCOPIC FEATURES

In thin section, also, the texture of the andesine-augite gneiss strongly resembles that of an igneous rock. (See pl. 6*D*.) The dominant mineral is andesine (An_{40} to An_{43}), which occurs in anhedral crystals. In three thin sections cut from specimens collected at different localities, the average length of the andesine crystals is about 0.1 inch and the greatest length 0.45 inch. In two of the sections, the crystals are weakly fractured (see pl. 6*D*.); in the third, the crystals are moderately fractured and are slightly offset along the fractures. The crystals are strongly twinned; some of them contain inclusions of fine-grained muscovite and a little clinozoisite.

The augite is colorless and nonpleochroic and has extinction angles of from 40° to 43°. Its average grain size is similar to that of the andesine. In thin sections the augite shows a wide range of alteration to uralite. Plate 6*D* shows the least alteration, in which there is only a thin rim of uralite around the augite, but in the other sections only small residuals of augite remain in pseudomorphous masses of uralite. The augite and uralite together constitute 5 to 30 percent of the rock. The uralite is partly altered to pale-green fine-grained chlorite except adjacent to ilmenite, where the alteration product is brown biotite, similar to the coarser primary biotite but finer-grained. The fine-grained chlorite permeates the fractures in the andesine, as if its constituents were distributed by the solutions that caused the alteration of the augite. The chlorite-filled fractures in the andesine show no genetic relation to the fine-grained muscovite and clinozoisite included in the andesine.

Anhedral quartz and orthoclase are commonly present in uneven amounts, but either mineral may be present without the other, and together or separately they are usually more abundant than augite. The quartz is rarely fractured, but shows mild undulatory extinction. The orthoclase is mildly fractured, is veined like the andesine with fine-grained chlorite and contains random and indistinct strain-twinning as does the orthoclase in the other gneisses. Some of the orthoclase, in irregular parts of the gneiss, occurs in large, sporadic crystals of porphyroblastic habit. This is particularly true of the body 1.3 miles east of the mouth of Stamp Creek. The rock that contains the sporadic porphyroblasts differs in the relative scarcity of the large crystals from the porphyroblastic gneiss of the facies having an andesine-augite matrix.

Deep-brown biotite is the most abundant of the minor constituents, but its amount is uneven. The biotite occurs in undeformed and unaltered plates of about the same size as the grains of the other minerals. (See pl. 6*D*.) Apatite, in euhedral to subhedral crystals, is an unusually plentiful and rather evenly distributed accessory mineral. Less evenly distributed accessory minerals are ilmenite, calcite, zircon, and pyrrhotite. Ilmenite is by far the most abundant of these, and its abundance seems to vary directly in proportion to that of augite.

PORPHYROBLASTIC GNEISS

FIELD DESCRIPTION

The porphyroblastic gneiss is strongly characterized by numerous large crystals of orthoclase, which give the rock a coarsely spotted appearance. The matrix of these crystals is feldspathic and medium-grained. In places it is light- to medium-gray and contains abundant parallel laminae of mica, which give the rock a coarse and strong foliation. In other places, the matrix is dark greenish gray and contains few laminae of mica but is thinly to thickly layered. Bluish quartz is a prominent constituent of the foliated facies of the gneiss and a less prominent constituent of the layered facies.

In mapping the porphyroblastic gneiss, it is impossible to differentiate the two facies according to the character of the matrix. This is due in part to the effects of weathering but in greater degree to the lack of a well-defined areal pattern of the two facies. They appear to occur at random and to intergrade, and the abundance of the large orthoclase crystals masks the transition or contact.

The orthoclase porphyroblasts range in length from 0.3 to 3.3 inches, and are mostly Carlbad twins. They are most abundant in the foliated rock, of which they may constitute as much as 80 percent. They rarely make up more than 50 percent of the layered rock.

In the foliated rock the porphyroblasts are anhedral to subhedral, with the long dimension parallel to the twinning plane and approximately parallel to the laminae of mica. The laminae are commonly abundant and persistent, and the porphyroblasts occur between them in more or less planar aggregates, as illustrated in plate 7*C*, which shows the porphyroblastic gneiss of most widespread occurrence.

There are two uncommon varieties of the porphyroblastic gneiss that occur sporadically in areas not more than a few thousand square feet in extent. In one variety, the porphyroblasts are more nearly equidimensional than those in the strongly foliated gneiss and constitute by far the greater part of the rock, being so abundant that they mutually interfere. Mica occurs interstitially in very thin, wavy laminae that give the rock an indistinct foliation, as shown in plate 7*D*. In the other uncommon variety, whose principal occurrence is on the north bank of the Etowah River at the mouth of Stamp Creek, the mica laminae are relatively thick and continuous, but the gneiss has a roughly fluted structure, and the porphyroblasts occur in striplike aggregates oriented parallel to the fluting. (See pl. 8*A*, *B*.) The fluted gneiss occurs only where structural attitudes are highly divergent within small areas, and the minerals are abnormally strained, as described on page 40.

The porphyroblasts in the layered or nonfoliated facies of the gneiss are subhedral to euhedral, are squarish to elongate, and are oriented at random. In even the best-formed crystals, however, the angles are slightly rounded, and the contacts of the faces with the matrix are slightly serrate. In some places the gneiss contains tabular remnants and wisps of the sharply bedded metasediments. The bedding of these rocks is parallel to the layered structure of the gneiss, and the contacts are gradational. (See pl. 8*C*.) Some of the inclusions are garnetiferous, and the gneiss near them is also garnetiferous—an association well shown on Stamp Creek, 0.6 mile southwest of Stamp Creek Church.

MICROSCOPIC FEATURES

The matrix of the common foliated facies of the porphyroblastic gneiss is similar in composition and structure to the oligoclase-mica gneiss; it consists mainly of oligoclase and quartz in addition to the mica laminae. The matrix of the less common layered facies consists principally of andesine, partly unralitized augite, quartz and irregularly oriented biotite; accordingly, the matrix corresponds in composition and structure to the andesine-augite gneiss.

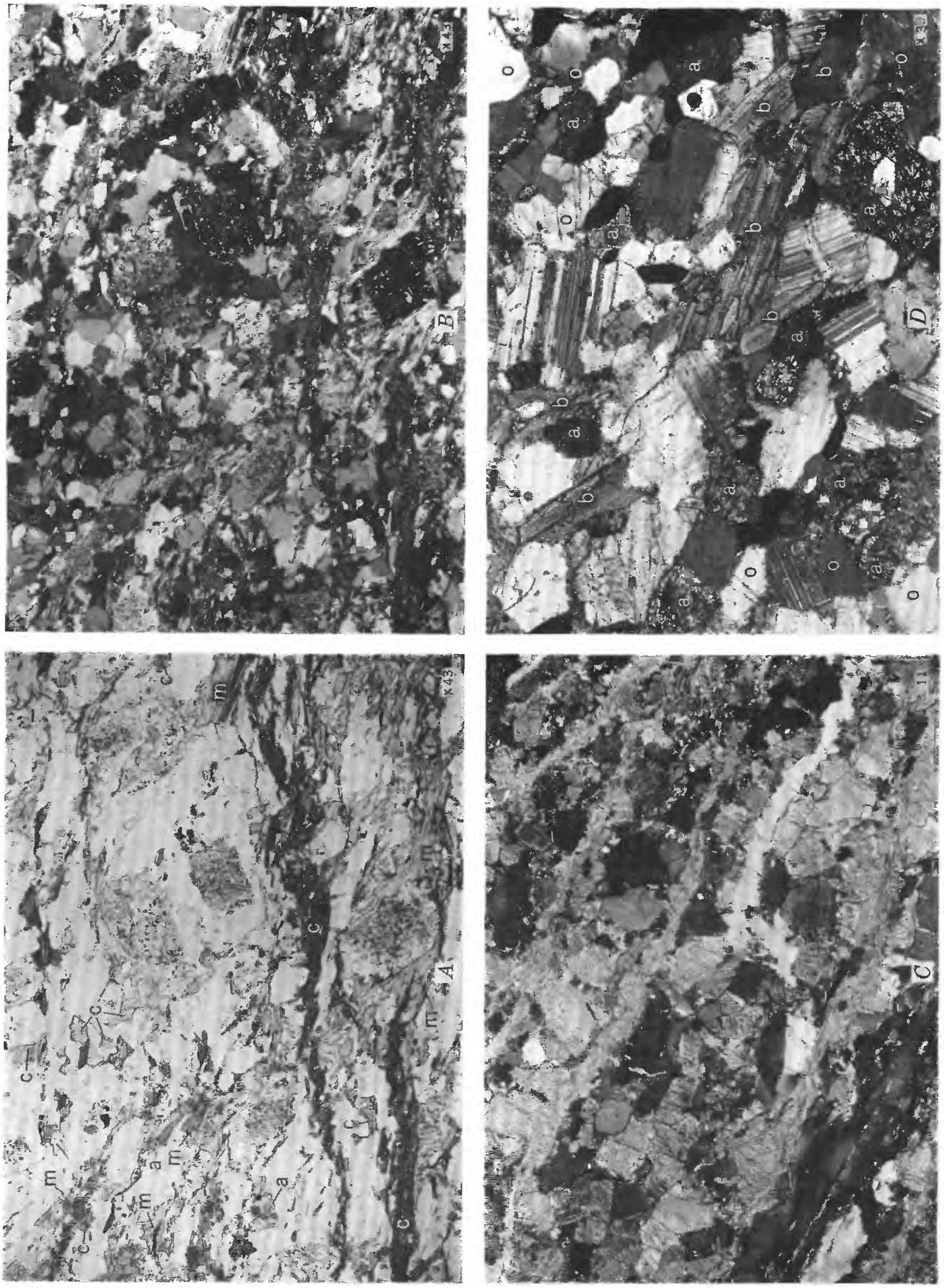
As the porphyroblastic gneiss differs from the two nonporphyroblastic gneisses only in the presence of the porphyroblasts, a description of the microscopic character involves only distinctive features related to the occurrence of the porphyroblasts. The differences are few and are summarized from a study of seven thin sections cut from specimens collected by the writer, and five thin sections examined for the Corps of Army Engineers.

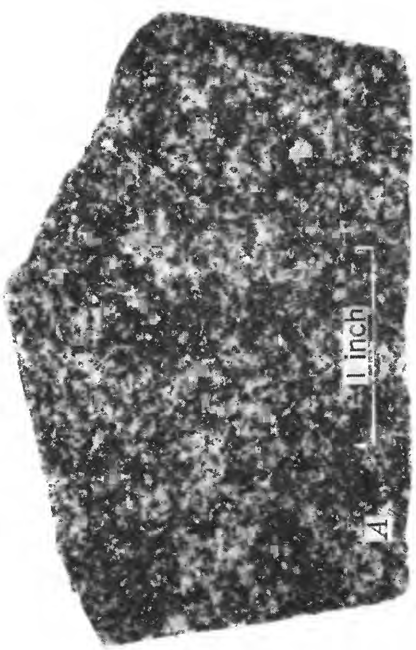
EXPLANATION OF PLATE 6

A, *B*, Photomicrographs of unweathered oligoclase-mica gneiss from dump at Allatoona gold mine. *A*, With plain light, showing oligoclase grains clouded with inclusions. Oligoclase, quartz, and orthoclase fill the lighter parts of the field. Other minerals are intercrystallized micas, *m;* calcite, *c;* apatite, *a*. *B*, With crossed nicols, showing lack of strain and fracture, and sporadic twinning in oligoclase.

C, Photomicrograph of oligoclase-mica gneiss with strongest foliation and maximum proportion of orthoclase. Mottled granular minerals are orthoclase and a little oligoclase; clear granular mineral with strain shadows is quartz; dense light-gray layers are muscovite laminae. Crossed nicols.

D, Photomicrograph of andesine-augite gneiss, showing texture of the rock and association of minerals. The andesine shows strong twinning. Other minerals are augite, *a*, marginally altered to uralite; biotite, *b;* orthoclase, *o;* black areas are ilmenite. Crossed nicols.

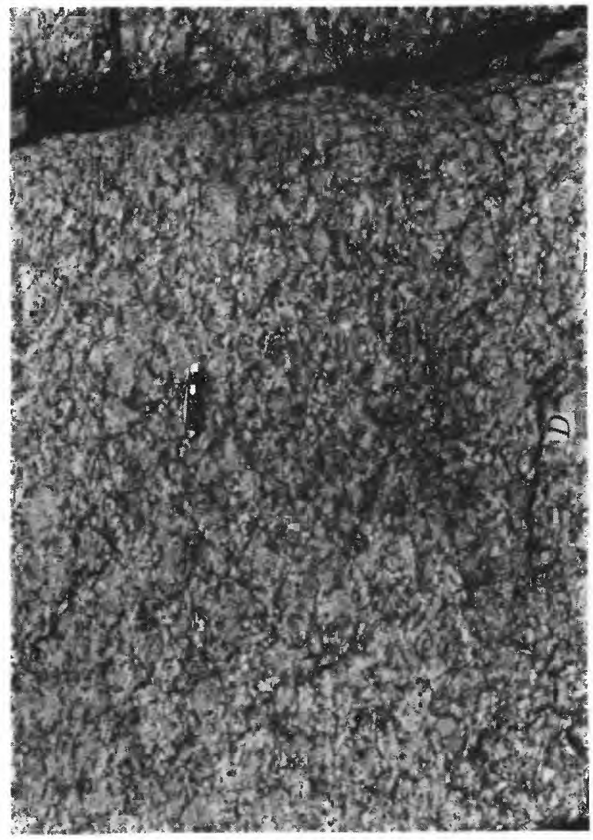




A


B


C


D

The orthoclase porphyroblasts of the more common foliated facies of the gneiss show moderate to strong effects of strain. Microline twinning is developed unevenly, and the crystals are commonly fractured, but offsets along the fractures are few and of slight displacement. Some of the fractures are healed with quartz continuous with that in the adjacent matrix; most of the quartz shows undulatory extinction. The oligoclase embays the porphyroblasts and apparently is of later origin. Some of the thin sections show effects of slight hydrothermal alteration, including clear sodic rims on grains of oligoclase, biotite partly altered to chlorite, and sphene partly altered to leucoxene. These features occur sporadically rather than generally in the gneiss.

The orthoclase porphyroblasts of the layered facies of the gneiss show milder effects of strain. They are commonly fractured but are not offset, and strain-twinning is very rare. The andesine also is mildly fractured and appears to have corroded the porphyroblasts, which may account for their rounded corners and uneven faces. Medium-grained orthoclase, which is not apparent in hand specimens, also is present and has the same relations as the porphyroblasts.

Some of the smaller andesine crystals along the margins of the porphyroblasts are irregular in shape and are myrmekitic, containing wormy intergrowths of quartz, as shown in plate 8*D*. The development of the myrmekite appears to be related to the corosion of the orthoclase, but the myrmekite occurs only sporadically along the margins of the orthoclase, although the latter appears to be everywhere corroded. Furthermore, myrmekitic texture is not limited to the finer grains of andesine, without definite crystal outlines, but occurs also in the outer parts of a few of the larger, strongly twinned crystals, which are commonly elongate parallel to the twinning. The myrmekitic parts of such crystals are all in contact with orthoclase, but other parts of the same crystals, also in contact with orthoclase, are not myrmekitic.

POST-CRETACEOUS SURFICIAL DEPOSITS

GENERAL FEATURES

Irregular surficial deposits of unconsolidated sandy clay, in places containing gravel and boulders, are common in the western part of the district and in the ridge belt. These deposits occur on slopes and broad divides, at altitudes between 800 and 1,200 feet. They are relatively thin, and their presence is concealed by topsoil and vegetation except where they contain abundant pebbles and boulders that occur as float. The thickness and character of these deposits, and even the presence of most of them, are clear only where the deposits have been dissected by erosion or exposed in mine openings. Owing to their obscurity and highly irregular occurrence, the deposits cannot be outlined without the aid of a drill, and hence they have not been mapped. Very thin deposits of recent alluvium, which border the larger streams, also have not been mapped, for they are less eroded and therefore more obscure than the older surficial deposits. The broader stretches of recent alluvium along the major streams are approximately outlined by the broad spacing of contours on the topographic base of plate 1.

The surficial deposits are of two types: the one, characterized by the presence of smoothly rounded pebbles and boulders, is alluvium, and the other, characterized by their absence, is colluvium. Deposits of the two types merge in some places and are apparently of contemporaneous origin, but their composition and distribution reflect a difference in mode of deposition. The age of the deposits cannot be stated definitely. The deposits are remnants of larger deposits formed during a period of aggradation that followed the final period of peneplanation in the Cartersville region, in post-Cretaceous time, as is indicated in the section on erosional history (pp. 50-51) which discusses the processes related to the origin of the deposits described below.

ALLUVIAL DEPOSITS

The deposits that contain the pebbles and boulders are less abundant than those which do not contain them, but their occurrance is more widespread. The pebbles and boulders consist of quartzite and vein quartz and are enclosed in red to yellow sand and sandy clay, that, in places, is obscurely bedded. Rarely, near barite deposits, a few of the rounded pebbles consist of barite. The coarser constituents are clearly water-worn, and this feature, together with the sporadic bedding in the sandy clay, indicates alluvial deposition.

Considerable transportation of the constituents of the alluvium is indicated by the distribution of the deposits. These are particularly numerous on

EXPLANATION OF PLATE 7

A, Polished face of andesine-augite gneiss.

B, Layered structure in andesine-augite gneiss.

C, Strongly foliated porphyroblastic gneiss of common occurrence. Outcrop 1 mile east of mouth of Stamp Creek.

D, Local, weakly foliated variety of porphyroblastic gneiss, on Etowah River 0.2 mile above the mouth of Stamp Creek. Foliation parallel to knife.

the lower hills south of Cartersville, near the Etowah River, where most of them overlie calcareous metashale that does not contain quartzite or vein quartz. The deposits are less numerous in the upper drainage areas of Pettit and Little Pine Log Creeks, but there also they overlie calcareous metashale and carbonate rocks lacking the quartzose rocks of which the pebbles and boulders consist.

The size and relative abundance of boulders in the alluvial deposits increase with proximity to the ridge belt. This feature is particularly well shown in deposits along the western flank of Little Pine Log Mountain, which contain large boulders in abundance. These deposits grade upslope and up the narrow valleys into accumulations of angular to semirounded quartzite blocks, which are essentially talus deposits derived from outcrops higher on the mountain. The transition occurs between 1,100 and 1,200 feet of altitude, and indicates the source of the material in the alluvial deposits.

The alluvial deposits occur, near the Etowah River, above 800 feet of altitude, and, in the northern part of the district, above 900 feet of altitude. Their deposition thus appears to be related to the present drainage system, although the streams have cut through the deposits everywhere except in their highest parts. A single exception to the range of altitude given above has been found 1.5 miles southeast of Cartersville, where a deposit of the alluvium occurs at an altitude of only 700 feet along U. S. Highway No. 41. This deposit is believed to have been formed by the erosion and redeposition of the alluvial material during the carving of the Etowah floodplain, and there are probably other such deposits in the lowland along the river, concealed by a blanket of silt.

COLLUVIAL DEPOSITS

The surficial deposits that do not contain smoothly rounded pebbles and boulders have a range of altitude similar to that of the alluvial deposits, and occur on slopes in and near the ridge belt that are underlain by carbonate rocks and calcareous metashale. They consist principally of deep-red sandy clay, much less compact than the underlying brown to yellow clays residual from the weathering of the carbonate rocks and calcareous metashale.

The red sandy clay commonly contains boulders of variable sizes. The boulders consist of jasperoid (described on pp. 47-49) and quartzite, and they occur in the clay wherever the underlying residuum contains boulders of jasperoid, and wherever quartzite of the Weisner formation crops out upslope above the deposits. The jasperoid boulders are angular to semirounded, as are those in the underlying residual clays, and the quartzite boulders are angular as are those which occur as float near the outcrops upslope. Near residual ore deposits the red clay also contains fragments of the residual ores.

These slope deposits of red clay and the irregular coarser constituents are exposed in the upper walls of most of the open-cut mines. Invariably they show no bedding or any evidence of sorting. Their constituents are derived from adjacent residual clays and rocks in place, and the deposits have obviously been formed by the downslope migration of erosional debris. The fine clay has been washed away during the process of migration, and the remaining material is coarser and more highly oxidized than the residual clays from which most of it is derived. The debris on the slopes has been called colluvium by Hull,[37] and the term is used in the present report. It distinguishes eroded material that has been deposited, with little abrasion or sorting, before reaching the stream courses.

The contact between the colluvium and the underlying residuum is sharp in some places and gradational in others. The sharp contacts appear to reflect an initial accumulation of debris, by sheet wash, on bare surfaces. The gradational contacts appear to reflect slower initial accumulation by soil creep.

The colluvial deposits are 2 to 10-feet thick in the walls of most of the open-cuts. The deposits lens out gradually upslope at the contact between the Weisner rocks, which crop out on the crests of the ridges, and the overlying calcareous rocks whose residuum occurs on the slopes. In the narrow headwater valleys, mostly between 1,000 and 1,200 feet in altitude, the colluvial deposits grade downslope into alluvial deposits in which the channels of the streams are cut. In the broader headwater valleys, mostly between 800 and 1,000 feet in altitude, the colluvial deposits commonly lens out rather abruptly above the floors, which contain no alluvium.

Locally, however, the colluvium occurs in rela-

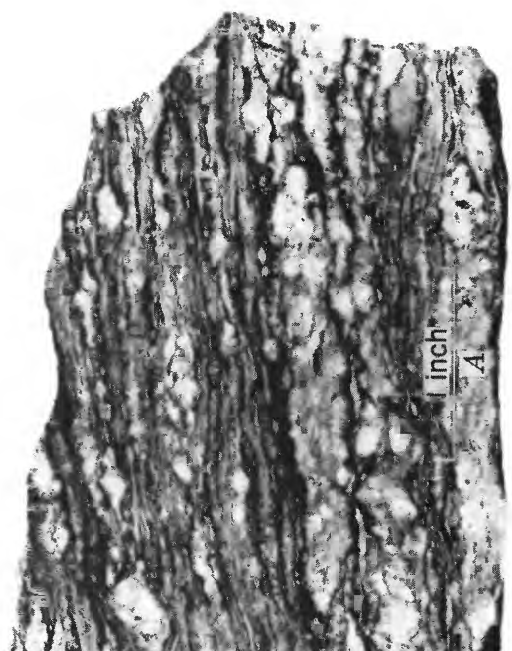
[37] Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, p. 15, 1920.

EXPLANATION OF PLATE 8

A, *B*, Local, fluted variety of porphyroblastic gneiss from mouth of Stamp Creek. *A*, Polished face parallel to axis of fluting. *B*, Polished face transverse to axis of fluting.

C, Inclusion of garnetiferous metasediment in garnetiferous porphyroblastic gneiss. Note gradational rather than sharp contacts near the hammer.

D, Photomicrograph showing andesine myrmekite marginal to orthoclase in porphyroblastic gneiss. Orthoclase, *o*; nonmyrmekitic andesine, *a*; most of the finer-grained material is quartz. Crossed nicols.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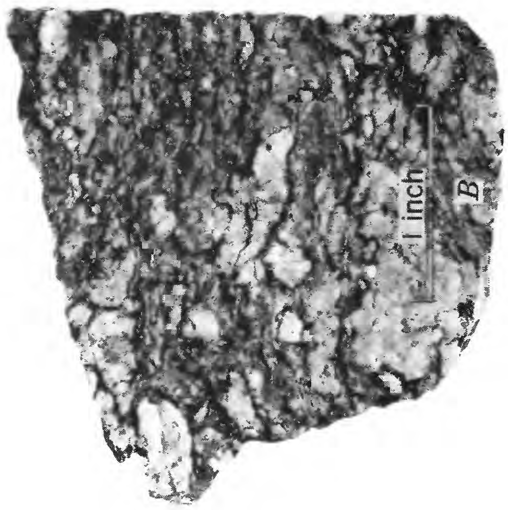
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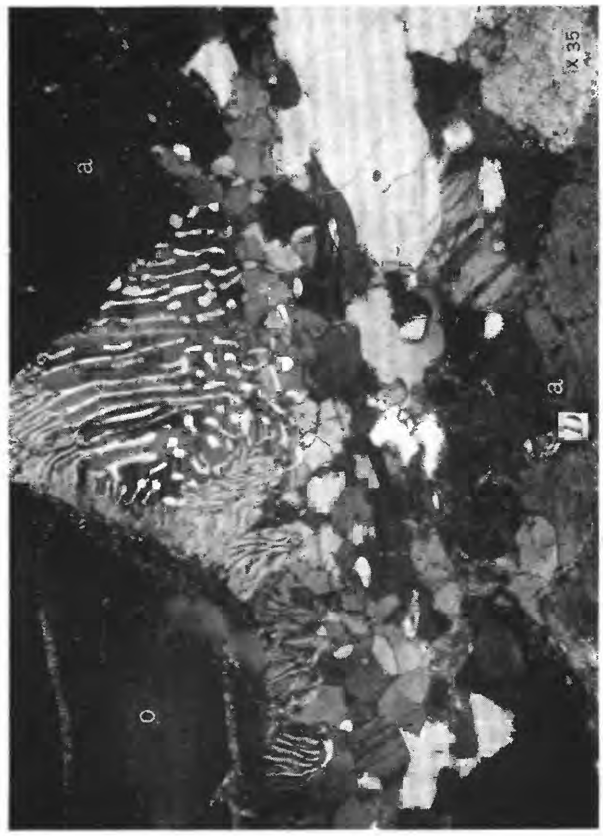
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tively flat parts of valleys underlain by carbonate rocks. These parts are invariably remote from the stream channels, and the colluvium in them thickens abruptly into pocketlike bodies that are believed to be filled sinkholes. One of these pockets at the Bufford mine contains about 90 feet of colluvium. (See p. 69.) The base of the pocket has about the same altitude as the lower limit of the alluvial deposits along the Etowah River.

STRUCTURE OF THE CAMBRIAN ROCKS

FOLDS

CHARACTER AND RELATION TO LITHOLOGY

The Cambrian rocks are folded throughout the district, and the beds in most places dip more than 40°. The prevailing direction of strike is northeast, and the prevailing direction of dip is southwest, but there is considerable variation, as is shown by the structure symbols in plate 1. The prevailing attitude suggests that the beds in most places are rather highly compressed in folds overturned toward the northwest. Few crests of folds are exposed, owing to the effect of deep weathering, but those that are exposed bear out the suggestion.

Small folds, whose amplitude ranges from 2 or 3 to perhaps 100 feet, are exposed in a few widely separated localities in metashale and thin-bedded amphibolite. These may be drag folds, but their extreme scarcity makes them of no value in outlining precisely and determining the pitch of the larger folds. Their chief structural value is to bear out the suggestion of westerly overturn afforded by the prevailing attitude of the rocks.

The larger anticlinal folds underlie the areas on the ridges in which the oldest or Weisner rocks crop out. All of the crests or flexures of the larger folds that are exposed in cross section are in the Weisner formation, for the quartzite is more resistant to weathering than any of the other rocks. Some of the crests are essentially uncrumpled and unfaulted; examples of these occur 0.6 mile due south of the Pine Hill mine, 1 mile southeast of White on the Wolfpen Gap road, and in the northern part of the town of Emerson. Other crests exposed in cross section are considerably crumpled and broken; examples of these occur 0.4 mile northwest of Bartow, and at the east cuts of the Dobbins mine.

It will be noted on the geologic map that structure symbols of both bedding and schistosity are used in areas underlain by the Cambrian rocks. The schistosity symbols are used where there are small outcrops of metashale containing no beds of more competent rocks. The foliation of the metashale in such outcrops is therefore not demonstrably parallel to bedding in the immediate vicinity, but the schistosity symbols in most places accord with adjacent bedding symbols. In outcrops of metashale interbedded with quartzite and dolomite, the foliation of the metashale is uniformly parallel to the bedding. (See pp. 29, 36-37.) The schistosity symbols are therefore as dependable as the bedding symbols in indicating the orientation of folds. The attitudes of shear and fracture cleavages, which are rare and of local occurrence (see pp. 29-30), are diverse and are not shown on the map.

The observed attitudes of all the rocks, and the cross sections plotted from them (see pl. 1), indicate that the folds in and to the east of the ridge belt are for the most part parallel, essentially isoclinal, and strongly overturned toward the west and northwest. In some parts of the ridge belt and the area to the west, however, the carbonate rocks of the Rome formation and underlying Weisner rocks have a westerly dip, and in the extreme northeast corner of the district the Conasauga rocks occur in undulatory folds.

The easternmost outcrops in which a westerly dip is noticeable occur along a rather indefinite course that connects the following localities: the mouth of Pumpkinvine Creek; the Paga No. 1 mine; the town of Cartersville; the western parts of Ponder, Dobbins, and Bufford Mountains; the crest of Little Pine Log Mountain; and the area northeast of Sugar Hill. Most of the metashales of the Rome and Conasauga formations, which overlie the carbonate rocks west of the course outlined, have an easterly dip, but these rocks, in contrast to those which in places have a westerly dip, are relatively incompetent.

To the west of the district the frequency of westerly dips increases, and the average angle of dip decreases regardless of the direction of dip. Thus, the Cartersville district contains a transition from the highly compressed folds typical of most of the Piedmont province to the asymmetric folds typical of much of the Appalachian Valley and Ridge province. The transition in the degree of compression of the folds is accompanied by a diversity in the orientation of fold axes that appears to characterize the district alone and does not include the region to the west. This diversity is reflected by wide differences in the strike of beds in random outcrops and by the lack of parallelism of some of the prominent anticlinal ridges, particularly those nearest the Roan, Howard, and Blue Ridge mines and those in the area northeast of Sugar Hill.

It is significant that the easternmost occurrence of asymmetric folds in the district and adjacent area coincides approximately with the eastern limit of the thick series of carbonate rocks of the Rome formation. These rocks constitute the only Cambrian stratigraphic unit that has an essentially uniform lithologic character; it consists almost entirely of relatively rigid dolomite and limestone. In contrast, relatively weak metashale constitutes the greater parts of the Weisner and Conasauga formations, and of the Rome formation farther east.

The manner in which the rocks yielded to compression directly reflects their relative average competence. Those in the eastern part of the district yielded in many highly compressed folds, indicating a low-average competence at the time of folding.[38] There was an increase westward in average competence, owing to the thickening of the carbonate rocks in that direction, and hence the stronger rocks yielded in less highly compressed folds, and the degree of compression diminished westward.

The weak metashales overlying the carbonate rocks west of the ridge belt are undoubtedly more contorted than the carbonate rocks themselves, for folds of much smaller amplitude than those in the carbonate rocks can be recognized in a few places in spite of the strong effects of weathering. Such contortion of thin beds overlying more evenly flexed massive beds has been clearly demonstrated in the experiments of Willis.[39] The contortion of the thin beds results in dip that is more uniform in random outcrops than that of the underlying massive beds.

EVIDENCE OF UNEQUALSHORTENING

The folds in the Cartersville district accord with those in the adjacent region, in their approximate parallelism and northeast orientation, except in the area between Ponder and Signal Mountains. In this area, there is a pronounced curvature in the trend of the folds, which have an abnormal orientation toward the northwest.

The experiments of Willis,[40] of Mead,[41] and of Hubbert[42] have shown that folds produced by uniform compression in the horizontal plane are straight and parallel regardless of whether the stress is rotational or nonrotational. It follows that any local, systematic departure from the prevailing trend of folds, in a region where the folds are otherwise straight and parallel, reflects a local modification of essentially uniform regional compression. As the folds express the shortening effected by compression, the local modification must have resulted from a local difference in the rate or amount of shortening, providing that the continuity of the folds is unbroken. Only a local difference in shortening, therefore, can account for the curvature in the trend of the folds between Ponder and Signal Mountains. Such a local difference undoubtedly would not affect the overall regional shortening, as it would logically be compensated elsewhere by a local difference of opposite kind. It is necessary, however, to consider the cause of the abnormal curvature here described in view of its genetic relation to local faulting and ore deposition.

A local difference in shortening suggests local difference in the resistance to regional compression, and, if the force were essentially uniform, a difference in resistance would indicate a difference in the strength of the rocks. The geologic map and cross sections (pl. 1) show no stratigraphic features west of the arc of curvature that are not present in the remainder of the western part of the district. A little farther west, however, the stratigraphy is appreciably different from that of any other area equally near the district.

The metashale of the Rome formation underlies the area between Cartersville and Ladd Mountain, 2 miles to the west, and contains carbonate rocks in much greater abundance than elsewhere. Exposures of these carbonate rocks, one of which is in the extreme western part of the town of Cartersville, are less common than those of the metashale because of deep weathering, but large sinkholes are unusually common throughout the area. The massive Knox dolomite, which is well exposed in a quarry on the east nose of Ladd Mountain, overlies the metashale of the Rome formation, and underlies all of the area between Ladd Mountain and Rome, 22 miles to the west. Hayes[43] has estimated the thickness of the Knox in this area as 4,000 to 5,000 feet, and the underlying Rome rocks, between Ladd Mountain and Emerson, are estimated by the writer to be about 2,000 feet thick.

At the time of folding, therefore, the geologic column included a greater thickness of relatively uninterrupted competent rocks in the area directly west of Cartersville than in any other part of the region adjacent to the district. The fact that the highly compressed folds along the eastern side of this area occur in an arc parallel with the eastern margin of the Knox dolomite, and convex toward the southeast, indicates clearly that compression acted from the southeast, and that an axis of resistance was developed approximately parallel with structure section line D-D′ on the geologic map. Northwest of Ponder Mountain, the carbonate rocks of the Rome formation are separated from the Knox dolomite by metashale of the Rome formation, less calcareous than that west of Cartersville, and by the Conasauga rocks, which appear to thicken northward. These intervening rocks are relatively incompetent. The average resistance to the compression of folds west of the ridge belt was therefore less, and the local shortening greater, in the area

[38] Leith, C. K., Structural geology, revised ed., p. 170, 1923.
[39] Willis, Bailey, The mechanics of Appalachian structure: U. S. Geol. Survey 13th Ann. Rept., pt. 2, pl. 90, 92, 1893.
[40] Willis, Bailey, op. cit., pp. 241-253.
[41] Mead, W. J., Notes on the mechanics of geologic structures: Jour. Geology, vol. 28, pp. 518-523, 1920.
[42] Hubbert, M. K., The direction of the stresses producing given geologic strains: Jour. Geology, vol. 36, pp. 75-84, 1928.
[43] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Rome folio (no. 78), p. 3, 1902.

northwest of Ponder Mountain than in the area to the southwest. The relation of this local difference in shortening to faulting, through the development of rotational stress, is discussed on page 28 and illustrated in figure 3.

It is evident that the major features of geologic structure in the district cannot be adequately considered apart from those of the adjacent region. The major features in the district are merely parts of large features whose relations are not apparent within its limits. These features and their relations have an important bearing on stratigraphy as well as structure and are discussed on pages 33-35.

AGE OF THE FOLDING

The time at which the Cambrian rocks in the district were folded can be inferred only from the relation of the folds to those of the adjacent region, with which they accord in general orientation and approximate parallelism. As the district is a part of the broad Appalachian belt of folded rocks, the deformation of its rocks must have been contemporaneous with that of the rocks in the belt as a whole.

It is generally believed that the deformation in the part of the belt that includes the Cartersville district occurred in late Carboniferous time, and that the intensity of compression diminished westward. These conclusions are based on the occurrence of late Carboniferous rocks in the westernmost folds, on the westward decrease in the extent of compression of folds, and on the apparent cessation of the deformation before the deposition of Triassic sediments in the Piedmont region.

Rocks of proved Carboniferous age occur nearest the district in the Rome quadrangle, 22 miles to the west across the prevailing strike; the Rome quadrangle also contains Cambrian rocks whose stratigraphic position is equivalent to those of the Cartersville district.[44] The folds in which these rocks occur are less highly compressed than those in the Cartersville district, but the folds in the two areas, and in the intervening area, are parallel. The Cambrian rocks in the district, therefore, were apparently folded in late Carboniferous time. The possibility that weaker deformation could have occurred between Cambrian and late Carboniferous times is recognized, but no evidence to support it has been found in the Cartersville district.

FAULTS

EVIDENCE AND CHARACTER OF FAULTING

The Cambrian rocks are cut by many short and diversely oriented faults. Those that have been found are shown in plate 1. They are probably only a few of the actual number, for thick residual clay covers the carbonate rocks and calcareous metashales, and the opportunity for mapping structural details is mostly limited to areas underlain by rocks more resistant to weathering. Most of the evidence of faulting therefore occurs in areas in which quartzite of the Weisner formation crops out at close intervals. Open-cut mining has exposed faults, however, in some areas of low relief partly underlain by the deeply weathered calcareous rocks and containing few outcrops of any bedrock.

The faults are closely associated with the mineral deposits. As most of the deposits occur in the carbonate rocks of the Rome formation and their residuum, the evidence of faulting is commonly found in outcrops of the Weisner rocks near the deposits, and in discordant relations between these rocks and adjacent bodies of ore-bearing residual clay. The faults that have been mapped are shown in plate 1 as solid lines wherever they are well exposed, and as dashed lines wherever they are inferred to extend into areas that lack outcrops.

The usual evidence of faulting in the Weisner rocks consists of conspicuous outcrops of coarsely brecciated quartzite cemented with limonite. Such outcrops are linear, though rarely straight, and are oriented mostly oblique to the strike of unfractured quartzite exposed in place in adjacent outcrops. Pyrite occurs in the less-weathered quartzite of a few of the breccia zones and is obviously the source of the limonite. As pyrite is the only ore mineral in the district that occurs in appreciable amount in both quartzite and carbonate rocks, the limonitic breccia zones in the quartzite are not limited to the environs of mineral deposits in carbonate rocks and their residuum. Breccia zones of this kind are particularly well exposed east of the Blue Ridge mine, south of the Bufford Mountain mine, south of the Moccasin mine, north of the Boneyard mine, and in the area between the Peachtree and Black Bank mines.

Fault relations between the Weisner rocks and the carbonate rocks of the Rome formation are indicated in plan in many places by abrupt offsets in the contact, as shown in plate 1. Open-cut mining has exposed some of these faults in section. Those which are best exposed occur in the Paga No. 1, New Riverside, Big Bertha, Tucker Hollow, Barium Reduction, and Parrott Springs barite mines; the Dobbins and Bufford manganese mines; the Cherokee, Knight, and Howard ocher mines; the Peachtree brown-ore mine; and the Green manganese and umber mine. A view of an open-cut made in mining manganese from a clearly defined fault zone at the Dobbins mine is shown in plate 9*A*. The cut is the westernmost of the two east cuts, and the structural relation of the Weisner rocks to the ore-bearing residuum is shown in plate 17. A similar discordant relation at the Section House mine is shown in plate

[44] Hayes, C. W., op. cit., pp. 2-3, structure-section sheet.

9B, but mining has subsequently been extended northward through the fault zone, and the relation shown is no longer exposed.

Masses of jasperoid breccia (pl. 13*B*) commonly occur in the residual clays adjacent to faults that cut the carbonate rocks of the Rome formation. Although these masses have been transported to some extent by slumping of the clay during weathering, they are clearly indicative of faulting where the fault is not exposed. Jasperoid is not necessarily indicative of the presence of ore minerals, however, as is shown farther on in the report.

The dip of the few fault planes and fault zones exposed in section ranges from 45° to vertical. It is impossible to determine even approximately the direction of motion along most of them or the total displacement along any of them. As the faults bring into discordant relations only rocks that normally occur in close succession, it is unlikely that the displacement along even the largest of them amounts to more than a few hundred feet. Some of the faults are described in the section on mines, and it will be seen that the obscuring effects of weathering permit nothing more than the determination of trend and direction of relative displacement.

RELATION OF FAULTING TO FOLDING

The faults cut the folds and are therefore of later origin. Diversely oriented faults undoubtedly intersect in places, as shown on the geologic map, but no zone of intersection has been found in which all the rocks are sufficiently unweathered to indicate the sequence of the ruptures.

The orientation of the faults provides the only clue to their origin and mutual relations. The orientation is roughly systematic, although the system is not ideally geometric. It will be noted that the faults have three preferred directions of trend: one direction is approximately parallel to the folds, and the others are highly inclined to the folds. Some of the faults show only one general direction of trend throughout their course, and others show a change of trend from one preferred direction to another.

The threefold direction of trend strongly resembles that of the three principal sets of fractures obtained by Mead[45] in his experiment involving rotational stress. Mead used a rectangular, paraffin-covered rubber sheet, one end of which he moved laterally, in the plane of the sheet, to generate stress in the hardened paraffin. This motion is equivalent to that caused by locally retarded shortening in the vicinity of Emerson, which developed the abnormal orientation in the trend of the folds between Ponder and Signal Mountains, as discussed on pages 26-27.

Mead's three principal directions of fracture are shown in fig. 3*A*, and may be correlated with the trends of the faults, which are shown in fig. 3*B*. The fractures developed parallel to the direction of movement, direction no. 1, correspond to the faults oriented in the northwest quadrant; the fractures developed parallel to the longer sides of the sheet, direction no. 2, correspond to the faults parallel to the folds or general trend of this part of the ridge belt; and the fractures developed normal to the direction of maximum elongation, direction no. 3, correspond to the faults oriented in the northeast quadrant.

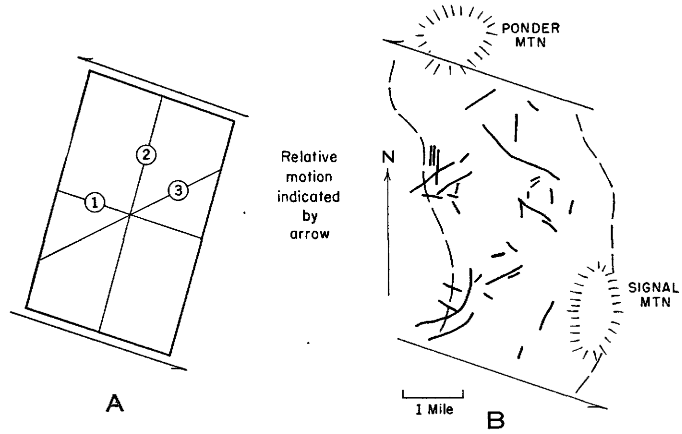

FIGURE 3.—*A*, Principal directions of fractures caused by rotational stress in experiments of Mead; *B*, Orientation of faults in ridge belt (bounded by dashed lines) between Ponder and Signal Mountains.

It will be noted that the systematic orientation of the faults is best developed in the area of abnormal orientation of the folds, shown in fig. 3, where the rotational stress was strongest. There is a much broader curvature, convex toward the northwest, in the trend of the folds between Ponder and Bear Mountains. The breadth and shallowness of this curvature indicates a much weaker rotational stress than that developed south of Ponder Mountain, and there is correspondingly a less systematic orientation of faults.

The apparent relation between faulting and folding indicates that rotational stress was a secondary rather than a primary factor in the deformation of the rocks. It was developed by locally unequal shortening through unequal resistance to compression, and in turn it formed the ruptures that are of prime importance in the economic geology of the district.

FOLIATE STRUCTURES

TYPES AND GENERAL DISTINCTION

The Cambrian metasediments in the Cartersville district contain three types of foliate structures, which are classified herein according to the definitions of Mead.[46] The classification is facilitated by well-preserved bedding in the rocks in nearly all

[45] Mead, W. J., op. cit., pp. 511-513, 1920.

[46] Mead, W. J., Folding, rock flowage, and foliate structures: Jour. Geol., vol. 48, pp. 1007-1021, 1940.

parts of the district. By far the most common type is bedding foliation, which is characterized by parallelism between bedding and the orientation of all platy and elongate minerals, even though the attitude of the bedding is diverse. Another, but rare, type is shear cleavage, in which there is a common orientation of muscovite in a plane that includes the strike of the beds, but the orientation is highly inclined to the bedding. The third type, fracture cleavage, which is also rare, consists of closely spaced planes of fracture that cut the beds and bedding foliation at high angles and in directions not parallel with the strike. The fracture cleavage, therefore, differs from the bedding foliation and shear cleavage in being not parallel to the platy and elongate minerals regardless of their orientation.

BEDDING FOLIATION

As previously stated in the lithologic descriptions, the metashales, which occur in all of the Cambrian formations, consist predominantly of very fine-grained muscovite. In most places, they are interlayered with sharply defined beds of quartzite, metasiltstone, or crystalline dolomite or limestone, and the bedding planes are therefore rarely obscure. Only in parts of the low ridges underlain by Conasauga rocks, west of U. S. Highway No. 411, is there any doubt about the relation of the foliate structure to bedding. In the outcrops, that expose both metashale and sharply defined beds of metasiltstone, on these ridges, the foliation is parallel to the bedding. Many outcrops, however, expose only metashale in which the bedding is not apparent. Its foliation in many places resembles slaty cleavage, but the attitude is diverse. It is possible, though not certain, that the foliation in such outcrops is discordant with the bedding.

With the rare exceptions noted in the description of shear cleavage, the muscovite in the metashales interbedded with all of the more competent rocks is oriented parallel to the bedding regardless of the direction in which the bedding dips. The orientation of the muscovite is rigidly uniform, with respect to the bedding, in very thick beds as well as in thin laminae, and gives the metashales a finely schistose structure. This structure has been observed in flat-lying beds in the crests of anticlines as well as in the beds on their flanks. Mead[47] defines such uniform parallelism between mineral orientation and bedding, where the attitude of the bedding is diverse, as bedding foliation to distinguish it from flow cleavage. In a similar environment, flow cleavage would be approximately parallel to the axial planes of the folds, and hence would commonly cut across the bedding. The origin of the bedding foliation appears to be related to the recrystallization of the Cambrian rocks, and is discussed in this connection on pages 36-37.

SHEAR CLEAVAGE

The foliate structure of the metashales is locally discordant with the dip, but not the strike, of bedding in irregular parts of the crests of a few anticlinal folds. Such discordance is best exposed in the north walls of the east Dobbins open-cuts, where thin beds of metashale and micaceous quartzite in an anticline have been crumpled and cut by small thrust faults. The foliation in some of the beds of metashale and the more highly micaceous beds of quartzite is parallel to the axis of crumpling, and inclined to the bedding. The muscovite is uniformly oriented parallel to the discordant foliation, and there is no evidence that bedding foliation had been previously developed. The structure is therefore believed to have been developed contemporaneously with the bedding foliation, but its rare and local occurrance indicates that the moscovite crystallized under local stress that prevented crystallization in the plane of the bedding. The orientation of the plane of crystallization is such as would result from rotational or shearing stress developed within the weaker beds by local and abnormal distortion. The origin of this structure is therefore different from that of the common bedding foliation, which is discussed on pages 36-37, and the structure is regarded as shear cleavage.[48] It has been observed to cut the bedding at angles of as much as 90° in metashale of the Weisner formation near Cartersville (see pl. 12*A*), and almost as steeply in micaceous crystalline limestone of the Rome formation on United States Highway No. 411, 0.3 mile north of Rydal.

FRACTURE CLEAVAGE

Fracture cleavage in the rocks of the district consists of parallel planes of rupture developed later than the folding and bedding foliation. It occurs locally and sparsely in every variety of the Cambrian rocks except the massive carbonate rocks. Wherever it has been observed, the fracture cleavage is discordant with the beds and bedding foliation in both strike and dip and consists of planes of rupture that cut the flexures of minute angular plications arranged parallel. As these planes are localized in the flexures, they are more widely spaced than the parting planes of bedding foliation and shear cleavage, which are derived from a common orientation of muscovite. The ruptured plications occur in very narrow zones oriented transverse or oblique to the strike of the rocks. Only seven of these zones have been found, and the one best exposed is shown in plate 9*C*. The outcrops are small, and the full length of the zones is unknown. Nowhere in the

[47] Mead, W. J., op. cit., p. 1009, 1940.

[48] Mead, W. J., op. cit., pp. 1010-1011, 1940.

district, however, have two or more of these zones been found to be mutually in strike. Consequently, the zones probably are quite short. Their occurrence is sporadic, for continuous outcrops in stream beds and road banks near the zones exposed show no similar structure.

The ruptured plications shown in plate 9C were clearly formed by movement along the zone, and the total displacement appears to be slight. It also appears that the movement occurred after the rock layers had acquired their tilted attitude. The only structural features in the district whose distribution and orientation are in any way similar to those of the zones of fracture cleavage here described are the faults. It is suggested, therefore, that these zones may have been formed contemporaneously with the faults but with less displacement.

JOINTS

Joints are common in the thicker beds of quartzite, but are very weakly developed in most parts of the district. Their occurrence is known more from the joint faces that characterize float boulders than from actual outcrops, which are commonly too small to facilitate a systematic study of the joints. The joints in most places occur in two planes, approximately at right angles and normal, respectively, to the bedding. The joints are as diverse in trend as the bedding. Local parts of massive beds are in places intensely jointed, as on the south slope of Ponder Mountain and immediately south of the Black Bank mine, but adjacent outcrops show very weak jointing.

QUESTION OF OVERTHRUSTING

The most prominent feature of previous geologic work in the district and its environs has been the divergence of opinion regarding the age of the rocks in the eastern part and their structural relation to those in the western part. The interpretation of age has influenced that of structural relation, and both have necessarily been based on inference owing to the scarcity of detailed information. Some geologists, including McCutchen,[49] King,[50] Hayes,[51] Watson,[52] and Crickmay,[53] have regarded the rocks in the eastern part as of pre-Cambrian age. Others, including Little,[54] McCallie,[55] Hopkins,[56] Shearer,[57] LaForge,[58] and Hazeltine,[59] have regarded them as of Cambrian or undifferentiated Paleozoic age. Hull[60] considered them to be of either Cambrian or Algonkian age, and Smith[61] believed that they include both Cambrian and pre-Cambrian rocks.

The geology of the Cartersville 30-minute quadrangle, which includes the mining district, was mapped by Hayes, Campbell, and Brooks in 1890 and 1895.[62] The map was not published, but Hayes in 1901[63] published a paper describing the geology of the mining district. This paper contains a geologic map whose principal structural feature is an east-dipping overthrust fault that trends north through the middle part of the district. The rocks west of it are shown as Cambrian, and those east of it as pre-Cambrian. These conclusions, regarding the major structural and age relations of the rocks, differed from others of apparently preliminary nature, which Hayes had published 10 years earlier,[64] and the difference was not explained. In the earlier paper, he had shown the trace of his overthrust considerably farther west, and had regarded the age of the rocks east of it as probably Silurian.

The trace of the overthrust as shown on Hayes' map published in 1901 can be projected only approximately on plate 1 of the present report, owing to considerable differences in scale and in the mapping of topographic detail. In general, it follows the flood plain of Pumpkinvine Creek from which it extends northward along the west sides of Signal and Pine Mountains, through the lowland east of the Appalachian mine, along the west slope of Wildcat Ridge, between Little Pine Log and Hanging Mountains, along the northwest base of Pine Log Mountain, and along the base of the upland north of Pine Log Creek.

LaForge[65] mapped the geology of the district on a larger scale, and in greater detail, during the period 1903-05, and he does not agree with Hayes.

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49 McCutchen, A. R., (Geology of Georgia) in Henderson, J. T., The commonwealth of Georgia, pp. 77-79, Atlanta, 1885.

50 King, F. P., A preliminary report on the corundum deposits of Georgia: Georgia Geol. Survey Bull. 2, pp. 68-69, 1894.

51 Hayes, C. W., Geological relations of the iron ore deposits in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans. vol. 30, pp. 406-408, 1901.

52 Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, pp. 12-13, 1906.

53 Crickmay, G. W., The ore deposits of the Cartersville district, Georgia: 16th Internat. Geol. Cong. Guidebook no. 2, pp. 127-128, 1932.

54 Little, George, Geological Survey of the State of Georgia, in James, T. P., Handbook of the State of Georgia, pp. 37, 47, Atlanta, 1876.

55 McCallie, S. W., Notes on the geology of Georgia: Jour. Geology, vol. 27, p. 168, 1919.

56 Hopkins, O. B., A report on the asbestos, talc, and soapstone deposits of Georgia: Georgia Geol. Survey Bull. 29, p. 4, 1914.

57 Shearer, H. K., Report on the slate deposits of Georgia: Georgia Geol. Survey Bull. 34, p. 47, 1918.

58 Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 40-41, 1919.

59 Hazeltine, R. H., Iron ore deposits of Georgia: Georgia Geol. Survey Bull. 41, pp. 83-84, 1924.

60 Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, pp. 21-23, 1920.

61 Smith, R. W., Shales and brick clays of Georgia: Georgia Geol. Survey Bull. 45, geologic map, 1931.

62 Hayes, C. W., Geologic folio of the Cartersville quadrangle, Georgia (manuscript report in files of U. S. Geol. Survey).

63 Hayes, C. W., Geological relations of the iron ore deposits in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, pp. 403-419, 1901.

64 Hayes, C. W., The overthrust faults of the Southern Appalachians: Geol. Soc. America Bull., vol. 2, pp. 141-154, 1891.

65 Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., pp. 52-53. LaForge, Laurence, Traverse and progress maps in files of U. S. Geological Survey.

LaForge concludes that there may be an overthrust whose trace extends from the flood plain of Pumpkinvine Creek, around the east side of the area underlain by porphyroblastic gneiss, around the north end of Pine Log Mountain, and along the valley of Pine Log Creek.

LaForge's map was never published, and the general interpretation of Hayes has persisted, with slight modification, in many subsequent maps of the Cartersville district, and of larger areas that include the district. The overthrust as mapped by Hayes has been retained even on maps that show the rocks to the east as of Paleozoic age. It is necessary, therefore, to review the basis on which Hayes mapped an overthrust and to consider it in the light of later information.

Hayes and his associates began their geologic work, in the region which includes the Cartersville district, in the Dalton quadrangle to the north. The following excerpt from Hayes' field report for June 1890 is especially interesting: "From these [three] camps the mountain region embraced in the sheet was worked. Fifteen days, June 4-18, were spent on this part of the sheet. From the 19 to 25 we covered the remainder of the Dalton sheet and adjacent portions of the Ringgold and Cartersville sheets. Since the 25 our work has been on the Cartersville and Rome sheets." All four sheets here mentioned are 30-minute quadrangles. The remainder of the report indicates clearly that the major correlations and interpretation of structure, which were projected southward into the Cartersville district, had been made by the end of the month. In view of the complex problems of stratigraphy and structure involved, such rapid coverage of so large a region can be classed only as reconnaissance.

Hayes cited very little direct evidence for the position of his overthrust. He stated[66] that the fault plane was observed at many places, and that its position is commonly indicated by a "bed of breccia" yet mentioned no single specific locality. The writer has closely examined the entire area in which the trace of the overthrust was mapped and has found that breccia occurs only along the faults shown in plate 1. These faults are oblique to the trace of the supposed overthrust, and Hayes apparently connected some of the exposures of breccia without carefully examining the intervening areas.

The attitude, moreover, of the plane of overthrust as described does not conform with actual conditions. The dip of the thrust plane was said to range from 5° to 20° east, and to be generally parallel with the cleavage and bedding of the rocks on either side.[67] As is shown, however, in plate 1, the rocks in most places along the course of the overthrust as mapped by Hayes dip at angles steeper than 45°. Furthermore, the beds have a greater diversity of strike than that of the supposed thrust. Prominently outcropping beds of quartzite trend obliquely across the mapped course of the thrust, without any break or distortion, at the Big Spring mine, on the southeast slopes of Little Pine Log Mountain, and in the valley of Little Log Creek south of the Sugar Hill mines. The critical area between Little Pine Log and Hanging Mountains has been examined with particular care, and the structure symbols in plate 1 show the structural continuity of the rocks in that area.

Recognizing that feldspathic gneiss and amphibolite occur in the eastern part of the district, Hayes[68] believed that the rocks with which they are associated are different in lithology from the rocks in the western part, but he noted that the rocks on the two sides of his overthrust at any given place are commonly alike. Although he and nearly all subsequent workers recognized that the rocks in the region west of his overthrust are metamorphosed in many places and that the rocks east of it show an eastward increase in the effects of metamorphism, they did not recognize that these features have any genetic relation. Hayes concluded that the rocks are different in lithology and therefore different in age, and his opinion is expressed in the following quotation:[69] "In the absence of fossil evidence, and because the rocks of this series [east of his thrust] have every appearance of extreme age, they have been correlated with the Algonkian." He referred to these rocks as "presumably older"[70] than those to the west, although he had previously considered them Silurian[71] in age.

Careful field and petrographic comparisons of the rocks, excluding the feldspathic gneisses and amphibolite, in the eastern and western parts of the district fail to show any fundamental difference between them. Quartzite, carbonate rocks, metashale, and metasiltstone have throughout the district the same sharply interbedded relations and similar mineral composition. There is a gradual, though somewhat uneven, eastward coarsening of textures (see pp. 35-36), but the textural relations of the minerals are not different in any respect, and the rocks near the

[66] Hayes, C. W., Geological relations of the iron ore deposits in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, p. 410, 1901.

[67] Hayes, C. W., op. cit., p 410.

[68] Hayes, C. W., op. cit., pp. 406, 410; The overthrust faults of the Southern Appalachians: Geol. Soc. America Bull., vol 2, pp. 148-149, 1891; Geologic folio of the Cartersville quadrangle, Georgia (manuscript report in files of U. S. Geol. Survey, pp. 17, 27-36).

[69] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, p. 408, 1901.

[70] Hayes, C. W., Geologic folio of the Cartersville quadrangle (manuscript report in files of U. S. Geol. Survey, p. 47).

[71] Hayes, C. W., The overthrust faults of the Southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 149, 1891.

trace of Hayes' overthrust have no peculiar lithologic characters. Crickmay[72] has suggested that phyllite (metashale) and albite-chlorite schist (slightly chloritic metashale) adjacent to the trace of Hayes' overthrust were formed by the retrogressive metamorphism of coarse-grained mica schists and biotite-garnet schists. This interpretation is hardly plausible, however, for the metashales near the trace of the thrust are indistinguishable from those farther away, and also contain sharply defined and undistorted beds of dolomite, quartzite, metasiltstone, and metaconglomerate whose mineral constituents and rounded pebbles are no more altered or deformed than those of similar rocks throughout the district.

In accordance with the prevailing opinion of his day, Hayes[73] regarded the feldspathic gneisses as basement rocks, of pre-Cambrian age, whose erosional waste furnished the materials of the other rocks that supposedly covered the gneisses prior to folding and metamorphism. Crickmay[74] has correctly pointed out that the main body of gneiss is younger than the adjacent metasediments. As Hayes viewed the problem, however, the occurrence of the supposed basement rocks on the downdip side of rocks in which a few Cambrian fossils had been found was altogether abnormal, and this was undoubtedly his principal reason for mapping an overthrust.

It is interesting to note the geologic conditions that caused Hayes to locate the trace of the overthrust where he did. Although he[75] recognized the nonuniform lithologic character of other formations farther west, he did not recognize this feature in the series mapped herein as the Rome formation. The carbonate rocks of the Rome formation and the overlying calcareous metashales have been weathered and eroded more rapidly than any other rocks in the district, and hence the areas underlain by them are relatively low. The metashale of the Rome formation becomes thicker, noncalcareous, and more resistant to weathering east of the carbonate rocks, so that there is a rather abrupt rise in the general topographic level, as well as a noticeable change in lithology, bordering the eastern-most of the larger areas underlain by the carbonate rocks. Accordingly, the trace of the overthrust was placed, in a general way, along the eastern limit of the more highly calcareous rocks except in the area south and east of Little Pine Log Mountain, but a few of the smaller lenticular bodies of these rocks were left isolated to the east. The deep and thorough leaching of the carbonate minerals evidently gave Hayes the impression that the calcareous rocks are unmetamorphosed, an impression which is discredited by a study of all thin sections cut from them.

The difference of relief between areas underlain by calcareous rocks and those underlain by noncalcareous rocks is most conspicuous in the southwestern and northeastern parts of the district. The dissected, sloping scarps in these areas are separated by the ridge belt, but they extend northward and southwestward far beyond the limits of the district. Hayes[76] believed that his overthrust is coextensive wtih the base of these scarps in the areas to the north and southwest, and the same interpretation is expressed on the recent geologic map of Georgia.[77] The writer's conclusion that the rocks along the trace of the overthrust in the district are conformable and in normal stratigrahic succession must therefore be applicable, to some extent at least, beyond the limits of the district.

No other area along the trace of the supposed thrust in Georgia has been mapped in detail, and consequently the conclusions reached in the Cartersville district can not be compared with any that have been reached on an equivalent basis. It is particularly difficult to compare them with the conclusions given in the few discussions[78] of broad, regional, geologic relations, that are based essentially on reconnaissance studies. These discussions not only are mutually incompatible, but they also contain major assumptions regarding stratigraphy and structure, which are not confirmed in the present report insofar as they apply to the Cartersville district. The great difference between the geologic conditions anticipated from earlier conclusions and those actually found in the district makes it apparent that discussions of the broad, regional relations will continue to be controversial unless the prerequisite data are provided by more detailed work in smaller but geologically important areas.

It has been shown in the foregoing appraisal of the basis on which Hayes mapped a major overthrust, that the entire area in which the structure was believed to occur has been carefully examined for supporting evidence, with negative results. All other parts of the district have also been searched with equal care for direct evidence of a similar fault, but without success. There seems, moreover, to be no valid indirect evidence in view of the detailed

[72] Crickmay, G. W., Status of the Talladega series in Southern Appalachian stratigraphy: Geol. Soc. America Bull., vol. 47, pp. 1387, 1390, 1936.

[73] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, p. 406, 408, 1901.

[74] Crickmay, G. W., op. cit., p. 1384.

[75] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Rome folio (no. 78), pp. 2-3, 1902.

[76] Hayes, C. W., The overthrust faults of the Southern Appalachians: Geol. Soc. America Bull., vol. 2, pp. 141-154, 1891.

[77] Georgia Geol. Survey: Geologic map of Georgia, 1:500,000, 1939.

[78] Keith, Arthur, Outlines of Appalachian structure: Geol. Soc. America Bull., vol. 34, pp. 309-380, 1923. Crickmay, G. W., Status of the Talladega series in Southern Appalachian stratigraphy: Geol. Soc. America Bull., vol. 47, pp. 1371-1392, 1936. Stose, G. W. and Stose, A. J., The Chilhowee group and Ocoee series of the Southern Appalachians: Am. Jour. Sci., vol. 242, pp. 367-390, 401-416, 1944.

accounts, elsewhere in this report, of lithologic characters and both small- and large-scale structural features. The diverse attitude of the rocks has facilitated the consideration of possible thrusting in many local areas. This feature is most conspicuous in the western part of the ridge belt, where there are many small and isloted ridges underlain by rocks of the Weisner formation. The most conclusive evidence of the stratigraphic order of the formations described herein is furnished by natural and mine-cut exposures on the flanks of these ridges. The exposures clearly show that the Weisner rocks dip conformably beneath the younger rocks that underlie the lowlands about the ridges. The Weisner rocks in these ridges, therefore, do not constitute remnants of a thrust sheet superimposed on the younger rocks.

It cannot be stated, however, that there is no thrust faulting whatever in the Cartersville district. The very small-scale thrusts mentioned on page 17 indicate that such structures may be very common, and the generally intense compression of folds makes it possible and even likely that there may be thrust faults of somewhat larger scale. But the carefully considered results of the present investigation appear to justify the conclusion that such faults, if they occur in the area, are short, are of relatively small displacement, and cannot be positively recognized.

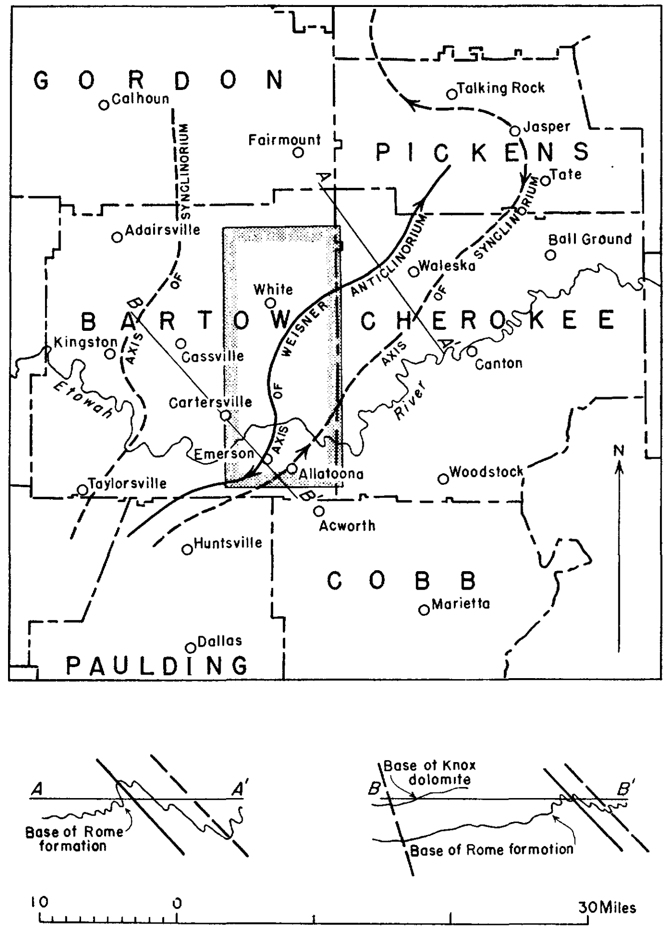


FIGURE 4.—Relation of major fold axes in region immediately including Cartersville district. Arrows indicate direction of plunge of axes.

TECTONIC RELATIONS IN THE IMMEDIATE REGION

The previous division of the Weisner rocks into two groups of different age, separated by the trace of a thrust fault, has served to obscure the principal structural feature in the Cartersville district and in the immediately adjacent region. The Weisner rocks crop out in anticlinal folds in the ridge belt between Emerson and Bear Mountain, as shown in plate 1. These folds are units of an anticlinorium that is continuous to the northeast for a distance of 14 miles beyond the border of the district. For convenience, this structure is termed the Weisner anticlinorium.

As shown on pages 26-27, the folds that make up this anticlinorium have an abnormal orientation in the southern part of the district, and this feature is the result of locally unequal shortening due to the unequal compression of folds in the rocks to the west. North of the area of abnormal orientation, the anticlinorium gradually resumes a normal orientation toward the northeast. Consequently, the axis of the anticlinorium is somewhat sinuous, and its relation to the trend of rocks in the adjacent region shows a structural pattern that is not evident in the limited area of the district. This pattern is shown in figure 4, which is based on the results of detailed work in the district, on much reconnaisance work in its environs, and on an interpretation of features shown on maps of adjacent areas.[79] A detailed correlation of geologic formations throughout the area cannot yet be made, for the number and relations of the formations are uncertain. The uncertainty arises from the generally recognized eastward increase in the effects of metamorphism, which are reflected by the transition from fine to coarse texture and from simple to more complex mineral composition of the rocks, without any change in their structural characteristics. The following outline of the major geologic structures, however, may assist in the correlation of the rocks.

Two major composite folds are apparent in addition to the Weisner anticlinorium. These are synclinoria, one of which occurs west of the anticlinorium and contains the very thick Knox dolomite previously referred to. The dolomite dips west in the eastern part of the synclinorium, and its unit folds farther west are broad and undulatory.

In the other synclinorium, which is east of the

[79] Bayley, W. S., Geology of the Tate quadrangle, Georgia: Georgia Geol. Survey Bull. 43, areal and structural geology sheet, 1928.

LaForge, Laurence and Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Ellijay folio (no. 187), areal geology and structure sections, 1913.

Georgia Geol. Survey: Geologic map of Georgia, 1:500,000, 1939.

anticlinorium, the unit folds are highly compressed. The metasediments exposed in the part of the structure east of Signal Mountain are largely metashales of the Rome formation. Lenticular bodies of the carbonate rocks in the Rome formation occur at the base of the metashales, but their full extent is unknown, because little of the adjacent area has been mapped in detail. The carbonate rocks are known to crop out north of Allatoona and southwest of Waleska, and thus identify the west limb of the synclinorium. They are correlated herein with the Murphy marble of the Tate and Ellijay quadrangles, which is believed to identify the overturned east limb. Similarly, lenticular bodies of amphibolite, which is correlated herein with the carbonate rocks (see p. 17), crop out sporadically in the synclinorium, but are most persistent along the east limb, in strike with the Murphy marble.

This eastern synclinorium was recognized farther north by LaForge and Phalen[80] and by Bayley,[81] and they believed that its axis coincides approximately with outcrops of the Murphy marble, which they placed at the top rather than the base of the series of rocks exposed in the structure. A reversal of the order, which would indicate that the axis must be farther west, as believed herein, is suggested by the following relations. The Rome rocks in the area north of Pine Log Creek are overlain by a great thickness of Conasauga rocks (see pl. 1), which, perhaps with even younger rocks, underlie the area east of Fairmount. These overlying rocks are continuous eastward around the north end of the Weisner anticlinorium at least to the vicinity of Waleska, but are not present near Allatoona, where the synclinorium is relatively narrow and shallow. As the structure is synclinal, the carbonate rocks should be exposed in its east limb, and the logical position of the east limb accords with the outcrops of the Murphy marble near Canton, Ball Ground, Tate, and Talking Rock.

Thrust faults have been mapped, in the works cited, in and along the belt of the Murphy marble and continuous southwestward toward and even across the southeast part of the Cartersville district. Careful search in this part revealed neither direct nor indirect evidence of a thrust fault, and consequently none is shown there in plate 1. The question of a thrust fault or faults in the Murphy marble belt is not important in the present consideration of the three major fold structures for, even if there is such faulting in that belt, its occurrence is a considerable distance east of the major folds, and has no direct bearing on their relations.

[80] LaForge, Laurence, and Phalen, W. C., op. cit., pp. 63-65 and structure sections.

[81] Bayley, W. S., op. cit., p. 114, and areal and structural geology sheet.

Figure 4 shows that the southern or distorted part of the axis of the Weisner anticlinorium is approximately parallel with the axis of the synclinorium to the west, but farther north the axes diverge. Throughout its course, the anticlinorium is approximately parallel with the synclinorium to the east, but the synclinorium bends around the northeast nose of the anticlinorium and then resumes a northeast course. This curvature of the axis of the synclinorium is similar to that of the axis of the anticlinorium in the vicinity of Emerson, though it is more acute and of larger scale. Furthermore, the bend is directed toward the area in which the western synclinorium veers away from the anticlinorium. These features are probably related in origin.

It can be assumed that the Weisner anticlinorium originated as a simple straight fold oriented northeast. The eastward thinning out of the carbonate rocks of the Rome formation may have served as an initial dip, which Willis[82] found essential for the localization of folding, but the development of additional folds was more acute eastward than westward owing to the relative rigidity of the carbonate rocks of the Rome and Knox formations to the west. The localization of intense compression east of the carbonate rocks is evidence that the rocks originally overlying the Weisner rocks that are now exposed were relatively weak. The eastward thinning out of the carbonate rocks of the Rome formation can probably only partly account for the relative weakness, and it seems likely that the Knox dolomite also must have thinned out eastward.

The rocks west of the anticlinorium had their greatest average rigidity in the area west of Cartersville (see p. 26), and the local resistance to shortening due to the compression of folds was relatively strong in that area. Farther north, the average rigidity was lower owing to the presence of the weak Conasauga rocks between the Rome and the Knox, and the shortening was greater in that area, producing the curvature in the anticlinorium previously described. Further shortening north of the curvature was prevented by the cohesion of the anticlinorium, in addition to the diminishing capacity of the Conasauga rocks to absorb compression. The wedgelike form of the Conasauga formation, which thickens northward, served to increase the distance between the anticlinorial axis and the synclinorial axis to the west.

The synclinorium east of the Weisner anticlinorium is a much longer structure than the anticlinorium, and its development was evidently influenced by the folding of the rocks to the west. The synclinorium is narrow and shallow in the area

[82] Willis, Bailey, The mechanics of Appalachian structure: U. S. Geol. Survey 13th Ann. Rept., pt. 2, pp. 247-250, 1893.

southeast of Emerson, where the resistance to shortening was greatest, but is broader and deeper to the northeast, where the resistance was less. The abrupt plunging of the obstructing mass of Weisner rocks west of Jasper produced a rotational stress similar to that which deflected the anticlinorial axis about Emerson. Compression was relatively unobstructed north of the anticlinorium owing to the remote position of the rigid Knox dolomite, and the synclinal axis was deflected around the northeast end of the anticlinorium. Thus a broad S-curve was developed in the trend of the axis and the strike of the rocks.

The rocks within the S-curve are oriented approximately parallel with the direction in which regional compression acted. Their abnormal orientation would have increased their resistance had compression continued, whereas the arcs of curvature would have been loci of weakness. It seems logical, therefore, that further regional compression would have constricted the arcs, forming sharp secondary folds with steeply inclined axes, such as those in Maryland, described by Jonas.[83] The example here described appears to represent an arrested stage in the development of these folds, and its apparent importance is to indicate that they may originate through unequal shortening during a single period of deformation.

ROCK ALTERATION NOT RELATED TO WEATHERING

RECRYSTALLIZATION OF THE CAMBRIAN ROCKS

EASTWARD COARSENING OF TEXTURE AND ITS SIGNIFICANCE

The preceding lithologic descriptions have shown that each variety of the Cambrian rocks contains the same assemblage of minerals, with similar textural relations, throughout the district. The only lack of uniformity is in the grain size of the minerals, which gradually increases eastward. The change is measurable only in thin sections, but it is apparent in an increasing roughness of feel of both the fresh and weathered rocks. The metashales are the most reliable indicators of the change, for they are of more widespread occurrence than the other types of rocks, are interbedded with all others, and were originally most nearly uniform in texture.

The metashales farthest west are argillitic to phyllitic, and locally slaty. They are brittle but rather soft even where unweathered, and their luster is dull to silky. The muscovite of which they principally consist occurs in plates mostly less than 0.1 millimeter long. The metashales farthest east are phyllitic to schistlike. They are brittle and hard, and their luster is semiglossy. The plates of muscovite are mostly 0.3 to 0.5 millimeter long. The eastward increase in the grain size of the muscovite is accompanied by a corresponding increase in the abundance of secondary quartz, which occurs in glassy pods and veinlets of megascopic size, and in irregular films and clusters of microscopic size.

These changes are not evenly transitional as is apparent, for instance, in the exposures of metashale of the Rome formation along U. S. Highway No. 41 in the narrow valley of Pumpkinvine Creek. These exposures show considerable variation in the texture and hardness of the metashale, but the variations are not continuous along the strike. Such local variations are common throughout the middle part of the district, but the overall change in the metashale from west to east, along any line across the strike, is one of gradually increasing coarseness. The change has been greatly obscured by differential weathering. The metashale of the Rome formation is calcareous in the western part of the district, where it overlies the carbonate rocks of the Rome formation and is there deeply leached and for the most part covered with residual and colluvial clays. To the east, where the carbonate rocks are present only in a few lenticular bodies, the metashale becomes noncalcareous, and is more resistant to weathering and more frequently exposed.

At ordinary temperature, water may recrystallize carbonate minerals in sedimentary rocks, but may cause only induration in rocks whose detrital minerals are normally insoluble. Both heat and water are believed to be essential for the recrystallization of sediments of diverse lithology, although the proportion of water involved may be very small.[84] The noncalcareous rocks as well as the carbonate rocks in the Cartersville district are not merely indurated but thoroughly recrystallized. Water probably was the solvent that effected transfer of the chemical constituents of the original minerals, and heat probably made the process possible by increasing the solubility of the minerals. Stress must also have influenced the process, as is discussed on pp. 36-37.

Neither the general increase eastward in the grain size of the minerals nor the local irregularities in the transition can be attributed to appreciable differences in the temperature of recrystallization. This is indicated by the uniformity of the mineral composition of the metamorphic rocks: if the temperature had been appreciably uneven, such relatively scarce minerals as garnet and pyroxene (see p. 37) would be much more common than they are, and other highgrade aluminous silicates would be present.

The transition cannot be attributed to differences

[83] Jonas, A. I., Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland: Am. Jour. Sci., 5th Ser., vol. 34, pp. 376-385, 1937.

[84] Harker, Alfred, Metamorphism, pp. 14-20, London, Methuen and Co., Ltd., 1932. Grout, F. F., Petrography and petrology, 1st ed., pp. 405-411, 1932.

in the amount of water that aided in recrystallization, for there is evidence even in the finest-grained rocks farthest west that there was sufficient water to transport mineral matter. Plate 10*A*, *B* shows photomicrographs of thin-bedded matasiltstone, containing laminae of metashale, from an outcrop 1 mile southwest of Aubrey Lake. The metasiltstone consists of intercrystallized orthoclase and quartz, with orthoclase by far the most abundant. It contains veinlets of the same minerals, as shown in plate 10*A*. The veinlets in the upper part of the photomicrograph are irregular, and may be filled openings of dynamic origin. Others are wedge-shaped and transect the bedding and appear to be filled dessication cracks. The comblike structure of the orthoclase and quartz in some of the wedge-shaped veinlets (See pl. 10*B*) shows that deposition occurred through crystallization rather than sedimentation. As there is no apparent source of the orthoclase other than the rock matrix, water must have been present in sufficient quantity to effect the transfer of material.

There were distinct differences in litholoic character among the beds of the original Cambrian sediments, and recrystallization has not obscured the distinction. Had the water essential for recrystallization been supplied from an extraneous source, it must necessarily have passed through all the rocks, effecting an interchange of mineral matter that would have obscured lithologic distinction. It is likely, therefore, that the water was contained in the original sediments. The small amount of it that was essential may have been present only in the hydrous minerals of the sediments, but it is likely that part of the water was present in the original pore spaces.

An extraneous source, however, is believed to have furnished the heat essential for recrystallization. The common occurrence of strongly folded sedimentary rocks of various ages shows that mere friction involved in folding has not developed the heat necessary for recrystallization. The eastward coarsening of texture previously described suggests that the source of heat was to the east of the district. The average temperature that prevailed during recrystallization would have been maintained longer near the source than at greater distance from it, owing to the diffusion of heat. It is therefore probable that the westward decrease in grain size of the minerals is proportional to the length of time during which the temperature necessary for recrystallization was maintained. The lack of absolute uniformity in the transition probably reflects uneven conduction of the heat, as a result of which local and irregular parts of the rocks acquired the necessary temperature later than the surrounding rocks and nearer the waning of the process.

ORIGIN OF BEDDING FOLIATION

The parallelism between the bedding and the foliation of metashales in all the Cambrian formations is a characteristic feature throughout the district. The parallelism is uniform regardless of the attitude of the bedding. The geologic map shows that there is considerable diversity in the strike of the beds and in the direction and amount of dip, but there is no systematic foliate structure superimposed on the bedding foliation, even in areas where the diversity is most pronounced. The shear and fracture cleavages previously described, which rarely and quite locally interrupt the bedding foliation, are not restricted to such areas.

The muscovite in the metashales is not deformed, but the recrystallized quartz in the quartzites and metasiltstones commonly though irregularly shows very mild to strong undulatory extinction. This feature in the quartz reflects strain developed after recrystallization, but its irregularity and wide range of intensity in all parts of the district can be correlated only with local and irregular stresses. These, in turn, may be correlated with the closing stage of folding, when the compensation of regional compression could hardly have occurred everywhere simultaneously. It is important to note that the condition of the recrystallized quartz is considered apart from that of detrital quartzose pebbles, for the strain shown in pebbles may in part predate the alteration of the rocks.

The shales, before they were folded or recrystallized, doubtless had the fissility that characterizes many of the older and originally more deeply buried shales. Lewis[85] attributes this structure to gravitational compression induced by loading, assisted by plastic flow on the depositional slope and by minor accessory processes. As the shales in the Cartersville district were interbedded with rocks more competent to transmit the force of compression, the folds that were formed are of the flexural-slip variety, in which the differential motion between beds is absorbed in the weaker layers by a slipping movement parallel to the bedding.[86] The fissility of shale would both facilitate, and be emphasized by, the slipping movement.

If recrystallization of the shales occurred contemporaneously with folding, the slip would develop friction between adjacent growing crystals of muscovite. The friction would occur principally along contacts more or less parallel to the slip plane and would be equivalent to unequal pressure on the crystals. As solution occurs selectively along surfaces subjected to

[85] Lewis, J. V., Fissility of shale and its relation to petroleum: Geol. Soc. America Bull., vol. 35, pp. 570-581, 1924.

[86] Knopf, E. B., Principles of structural petrology, in Knopf, E. B., and Ingerson, Earl, Structural petrology: Geol. Soc. America Memoir 6, pp. 159-161, 1938.

maximum stress,[87] the crystals would develop with relative freedom in the plane parallel to such surfaces. This plane, in shales recrystallized during flexural-slip folding, would be parallel to the bedding.

SELECTIVE SILICATION OF CALCAREOUS ROCKS

Near contacts with the porphyroblastic gneiss shown on the geologic map, some of the sporadic beds of originally calcareous metasiltstone, in both the Weisner formation and the metashale of the Rome formation contain reddish-brown garnet accompanied in places by augite. These minerals occur so irregularly that the beds containing them cannot be outlined on the map. These beds are most common on Redtop Mountain, along the Etowah River immediately east of Redtop Mountain, on a conical hill 2 miles east of Double Springs Church, and near the mouth of Hawks Branch. The surface at these localities is strewn with residual fragments and slabs of the rock, which contain small reddish-brown cavities left by the partial weathering out of the garnet.

Another abnormal variety of the metasiltstone, which occurs in the same environment, crops out in the bed of Hawks Branch, 0.8 mile north of Campbell Hill. This rock contains much zoisite and a little greenish-brown phlogopite.

In the southeastern part of the district, as shown on the geologic map, the amphibolite is very closely associated with oligoclase-mica gneiss. These rocks are in contact in much of that area, and the amphibolite does not occur at any considerable distance from the gneiss.

In the same area, chloritic parts of metashale of the Rome formation contain garnet, and the garnetiferous rock occurs only near oligoclase-mica gneiss. It crops out 1.8 miles due west of Payne, and 1.2 miles southwest of Allatoona, but owing to the scarcity of adjacent outcrops it cannot be delimited from the nonchloritic metashale.

The normal unweathered varieties of the metasiltstone and chloritic metashale are weakly to moderately calcareous, as the foregoing lithologic descriptions have shown. The correlation of the amphibolite with the Rome carbonate rocks (see p. 17) implies that the amphibolite was derived from a strongly calcareous, though perhaps shaly, original rock. It appears, therefore, that silicate minerals not found generally in the rocks of the district occur only in rocks that were originally calcareous, and only near feldspathic gneisses. The gneisses are younger than the other rocks (see pp. 42-45), and the association indicates that the development or deposition of such minerals as garnet, augite, hornblende, phlogopite, epidote, and zoisite was effected by the gneisses or by solutions related to the gneisses. The composition of the plagioclase in the amphibolite, which is similar to that in the oligoclase-mica gneiss, may also be indicative. The regional distribution of the amphibolite with respect to the oligoclase-mica gneiss, as shown on the State geologic map,[88] resembles that of a metamorphic aureole.

SOURCE OF HEAT

Although abnormal minerals were in places developed or deposited in calcareous metasediments near the younger feldspathic gneisses, the general eastward coarsening of all the Cambrian rocks in the district and adjacent region shows no relation to the geographic position of the gneisses. Recrystallization cannot therefore be attributed to the influence of the gneisses, because it was obviously of regional scope whereas the gneisses occur locally and irregularly.

Heat in amount sufficient for widespread recrystallization could have come only from a large and widespread magmatic source. In the Southern Appalachian region, the only intrusive bodies of post-Cambrian igneous rock, which are both large and widespread, consist of granite. The term as used here does not include granitic gneiss. The granite occurs in large, irregular bodies throughout the Piedmont region, and even in the Blue Ridge. All observers agree that the invasion occurred in late Carboniferous time, but some observers regard it as having accompanied[89] the Appalachian folding, and some as having followed[90] that folding.

As the source of the granite is in depth, it would not be reasonable to conclude that the bodies exposed indicate the entire extent of the invasion. It is possible that these bodies are cupolas or stocks, and that their wide and irregular occurrence indicates a parent batholith of regional extent. The older rocks nearest such a batholith might be strongly altered, but those nearer the outer limit of its influence would probably be affected only by low-grade heat-induced recrystallization such as that described above.

The inference that heat was derived from a Piedmont batholith in late Carboniferous time is consistent with the geologic history of the adjacent region and best accounts for the eastward coarsening of texture. No Carboniferous granite is exposed in the district, but the presence of feldspathic gneisses, which consist largely of alkalic feldspar and quartz and are younger than the Cambrian rocks, indicates a not very remote igneous body of granitic

[87] Johnston, J. and Niggli, Paul, The general principles underlying metamorphic processes: Jour. Geology, vol. 21, pp. 608-610, 1913.

[88] Georgia Geol. Survey: Geologic map of Georgia, 1:500,000, 1939.

[89] Keith, Arthur, Outlines of Appalachian structure: Geol. Soc. America Bull., vol. 34, p. 366, 1923.

[90] Jonas, A. I., Structure of the metamorphic belt of the Southern Appalachians: Am. Jour. Sci., 5th ser., vol. 24, p. 230, 1932.

character. The origin of the gneisses, which is discussed in the following section, postdates recrystallization and is attributed to emanations expelled from stocks that were intruded to relatively shallow depth from the main batholith. The development of garnet and augite in metasiltstone, and the alteration of carbonate rocks of the Rome formation to amphibolite, are attributed to the later emanations from the stocks, for these are features that are associated only with the feldspathic gneisses.

ORIGIN OF THE GNEISSES

SIGNIFICANT FEATURES

There is no single line of evidence to indicate the mode and time of emplacement of the feldspathic gneisses. The features discussed below, however, are important in indicating which of several possible modes of emplacement is the most probable, and at what time the emplacement occurred.

CONTACT RELATIONS AND INCLUSIONS

Early in the course of the field work, it was found that the contacts between the porphyroblastic gneiss and the metasediments are far more complex than previous descriptions of the geology would lead one to expect. It was also found that the main body of the gneiss encloses many bodies of metasediments that have a very great range in size. It was clear that no dependable inference regarding the relation of the gneiss to the metasediments could be made unless the contacts were carefully mapped in detail. This was accordingly done with the surprising result shown on the geologic map. Inclusions large enough to be mapped are shown, but there are many that cannot be shown on the scale employed. Nine small bodies of the gneiss also were found in the metasediments; their occurrence and contact relations are similar to those of the main body of the gneiss. Most of them are near the margin of the main body, but two of them are 3 miles southwest of it.

The invariable characteristic of all contacts is a strict parallelism between the bedding of the metasediments and the foliation of the gneiss, regardless of whether or not the contact is parallel to the bedding. Contacts parallel to the strike of these structures are relatively sharp, although metashales adjacent to them are in places gneissoid owing to the presence of secondary feldspar and quartz. The numerous contacts that locally transgress the strike of bedding and foliation are mostly covered by erosional debris and vegetation, but near such contacts, many small, closely adjacent outcrops project through the soil and are exposed in gullies. None of these outcrops show any departure from the parallelism in strike and dip of bedding and foliation. The frequency of transgressive contacts, and the uniformity of the attitudes near them, are shown on the geologic map. In view of their large number, it seems that any deviation would have been discovered. The uniform parallelism of bedding and foliation is reasonably good evidence that the transgressive contacts are gradational, and the conclusion is substantiated by the common presence of float masses of metashale, like that shown in plates 11 and 12, that are highly impregnated with feldspar and quartz. The hachured symbol used to indicate such contacts expresses the actual relation of the rocks in plan, and the results of core drilling by the Corps of Army Engineers at Allatoona dam site have shown that the contacts are fully as complex in the vertical plane.

The inclusions in the porphyroblastic gneiss range in length from a few feet to nearly 3 miles, and all of them are alined parallel with the local strike of bedding and foliation. The alinement of the larger inclusions is shown on the geologic map, and plate 8*C* shows the similar alinement, as well as gradaional contacts, of a small inclusion 0.6 mile southwest of Stamp Creek Church. It will be noted on the map that the area underlain by the Weisner formation has its greatest width north of the main body of the porphyroblastic gneiss, and that the eastern part of the Weisner rocks in that area is truncated by the gneiss. Farther south, the larger inclusions in the western part of the gneiss consist of quartzite and metashale identical with those of the Weisner on the west side of the gneiss. The overall width of the Weisner formation west of the gneiss plus the inclusions in its western part is consistent with that of the Weisner north of the gneiss, if allowance is made for the southward plunge of the Weisner anticlinorium.

The contacts of the oligoclase-mica gneiss are poorly exposed, as the effects of weathering are strong and uniform, and the relief low, in the areas that it underlies. Its foliation, near all contacts with the adjacent rocks, is parallel with their structure, but the outcrops near the contacts are not sufficiently close together to give the close control that is possible with the porphyroblastic gneiss, and, because of the uncertainty, interfingering rather than hachured contact lines are used. The relation of this gneiss to the metashale of the Rome formation is known from the occurrence of inclusions exposed in it in a road cut 0.7 mile south of Allatoona. The inclusions contain a few beds of strongly weathered, granular rock that appears to be metasiltstone. Both the metashale and the granular rock contain relatively coarse-grained feldspar and quartz, and in places resemble the enclosing gneiss. The metashale definitely grades into the gneiss across the strike—although the relation cannot be traced along the strike—and the mica laminae, which diminish in number in the transition, are identical with those which give the gneiss its foliation.

Near contacts with the amphibolite, the oligoclase-mica gneiss is commonly pale green, but is so thoroughly weathered that its mineral composition and texture are not evident. The relation of the gneiss to the amphibolite, however, is well exposed in outcrops in one of these contact zones along U. S. Highway No. 41, half a mile south of the margin of the district. In these outcrops the gneiss is but moderately weathered. It is hornblendic rather than micaceous, is weakly foliated, and is clearly a local facies of the normal oligoclase-mica gneiss, with which it is continuous along the strike. The rock contains irregular highly hornblendic layers, which differ from the adjacent amphibolite only in being coarser-grained and in containing an abnormally large proportion of feldspar, part of which is orthoclase. Irregular wads of orthoclase-bearing pegmatite, without sharp walls, occur in the gneiss. The pegmatite contains light olive-green hornblende crystals as much as 2 inches long, whose abundance increases as the pegmatite grades into the gneiss. The hornblende beyond the limit of permeation of the pegmatite is mostly of the normal, fine- to medium-grained, dark-green variety. The outcrops appear to indicate that the amphibolite underwent a progressive alteration whose principal effects were a general coarsening, the introduction of orthoclase, and apparently the elimination of hornblende. The alteration was most pronounced where orthoclase was locally deposited in greatest abundance.

RELATIONS OF THE PRINCIPAL MINERALS

MUTUAL RELATIONS

As the lithologic descriptions have indicated, there are in the district only two fundamental varieties of feldspathic gneiss, the oligoclase-mica rock and the andesine-augite rock. The porphyroblastic gneiss is essentially a complex of these rocks, obscured by an abundance of orthoclase porphyroblasts that make its distinction necessary. Orthoclase also occurs in the oligoclase-mica and andesine-augite gneisses but it is irregularly distributed and rarely forms porphyroblasts.

The relation of the orthoclase to the other minerals is the same in all the gneisses. It is characteristically embayed and corroded by quartz and plagioclase, and, where strongly fractured, is veined commonly with quartz and rarely with plagioclase. Wherever these minerals show the effects of strain and fracturing, the orthoclase is the most severely deformed. The full significance of the myrmekitic plagioclase is not clear (see pp. 20-21, 23), for the plagioclase in the myrmekite has the same composition as the nonmyrmekitic plagioclase; it is definitely not more sodic. It cannot be stated positively that the myrmekite is of later origin than the nonmyrmekitic plagioclase, but it is clear that both corrode the orthoclase. All the evidence, therefore, indicates that the orthoclase is older than the quartz and older than all the plagioclase.

The augite may be older than the orthoclase. It is weakly to strongly altered to uralite even where the other minerals show no evidence of strain, fracturing, or alteration. As the alteration of the augite shows no relation to the deformation or alteration of the enclosing rock, it is possible that the mineral is of early origin and that its alteration occurred prior to or during the crystallization of the other minerals.

LAYERING AND FOLIATION

Layered structure, as distinguished from foliation, is restricted to the andesine-augite gneiss and to the irregular parts of the porphyroblastic gneiss having a groundmass of similar mineral composition. The layering appears to reflect differences in the proportions of augite and biotite, particularly the latter, for the most prominent layers in the porphyroblastic rock are those that contain the most biotite. The relations of the andesine, quartz, augite, and finer-grained orthoclase are the same in the different layers regardless of the presence or absence of porphyroblasts. Where the porphyroblasts are present, they are isolated rather than clustered in all layers except a few that are relatively dark-colored, fine-grained, and in most cases ill-defined. The porphyroblasts commonly transect the layered structure, are oriented at random across it and within the layers (see pl. 9*D*), and have the same characteristics in all layers.

Foliate structure chacterizes the oligoclase-mica gneiss and all of the porphyroblastic gneiss except the irregular parts having an andesine-augite groundmass. The structure is formed by thin, parallel, and discontinuous lamellar aggregates of muscovite with or without biotite, and the mica plates are oriented parallel with the plane of the laminae. The other minerals occur principally between the laminae, but also commonly in them. Conversely, isolated plates of the micas occur between the laminae. In both environments, some of the mica plates abut sharply against crystals of the other minerals, and others curve around them as though diverted from parallelism with adjacent plates. The two features are commonly in evidence about the margin of a single crystal.

Evidence regarding the relation of the orthoclase porphyroblasts to the mica laminae is largely megascopic owing to the great contrast in grain size. The porphyroblasts commonly occur in aggregates of subhedral crystals that pinch and swell between the laminae (see pl. 7*C*) and less commonly as subhedral to nearly euhedral individual crystals, some of which occur between the mica laminae although others transect them. The bluish quartz occurs in relatively large irregular pods and sheets, which are mostly parallel with the laminae but in places cut obliquely across them. The laminae—rather than the individual mica plates—in some places curve around the aggregates of porphyroblasts, and in other places abut sharply against them. A single lamina may curve around one aggregate and abut against another.

The porphyroblasts and the quartz have a common relation to the mica laminae, regardless of the amount of strain and fracturing that is evident in thin section. These minerals show maximum deformation in the local fluted variety of the gneiss shown in plate 8*A*, *B*. The orthoclase and the quartz occur mostly in aggregates between the mica laminae, although some of the smaller porphyroblasts, together with crystals of oligoclase, occur within them, as shown in plate 10*C* (compare with pl. 6*C*). The quartz fills fractures in the orthoclase. Plate 10*D* shows that the orthoclase is strongly fractured, though not appreciably displaced, and the quartz severely strained. The fine-grained material gives the impression that much of the orthoclase has been crushed, but a large part of this material is quartz.

PORPHYROBLASTS AND VEINS IN THE CAMBRIAN ROCKS

Orthoclase similar to that in the gneisses occurs locally in the Weisner, Rome, and Conasauga formations at many places in the district, some of them more than 5 miles from the nearest outcrop of gneiss. The orthoclase occurs as porphyroblasts and augen-shaped pods in metashale at 13 localities; with quartz and calcite in thin veins in dolomite at 3 localities; and with quartz alone in veins in metashale, metasiltstone, and quartzite at 30 localities. The localities are designated on the geologic map. In view of the obscuring effects of deep weathering, and of the common presence of soil and colluvial cover, these occurrences probably are only a small proportion of the actual number.

The Allatoona Dam on the Etowah River has been constructed since the discovery and examination of the 46 localities mentioned above. Along the new road that leads to the dam, cuts that are 0.8 to 1.2 miles downstream on the south side of the river expose abundant pods and thin veins of orthoclase in metashales of the Weisner and Rome formations. The feldspar is so plentiful in places that small parts of the metashales resemble porphyroblastic gneiss.

Pods and porphyroblasts of the orthoclase in fine-grained metashale are best exposed 1.2 miles west of the Kelly mine, in the southwest bank of Pumpkinvine Creek. The metashale contains thin beds of metasiltstone and conformably underlies a lenticular body of dolomite. The orthoclase occurs in individual ovoid crystals and in podlike aggregates of crystals oriented parallel to the bedding, as shown in plate 11*A*. Its mode of occurrence is identical with that of the orthoclase in the porphyroblastic gneiss. Similar occurrences of orthoclase in fine-grained metashale are shown in plate 11*B*, *C*. The crystals and aggregates show a pronounced tendency toward orientation in the plane of lamination, but some of the crystals in the specimen from Hanging Mountain cut across the laminae.

The numerous orthoclase-bearing veins that have been observed range from a fraction of an inch to 10 inches in thickness. Some are parallel with the bedding; others cut the bedding at low angles. Those in metashale and quartzite contain a little quartz; those in dolomite contain both quartz and calcite, and it is inferred that the calcite was derived from the host rock. An unusual occurrence of an orthoclase vein, exposed during the construction of the west abutment of the railroad bridge over the Etowah River, is shown in plate 12 *A*. The vein occurs in a zone of shear cleavage, which is parallel with the handle of the hammer, and cuts the cleavage at a low angle. Pods of orthoclase, also shown in the photograph, occur above the vein. As the bedding is not appreciably displaced, these pods are not displaced segments of the vein but, like the vein, were deposited after the shear zone was formed.

Orthoclase veins containing quartz and calcite are exposed in dolomite of the Rome formation at the

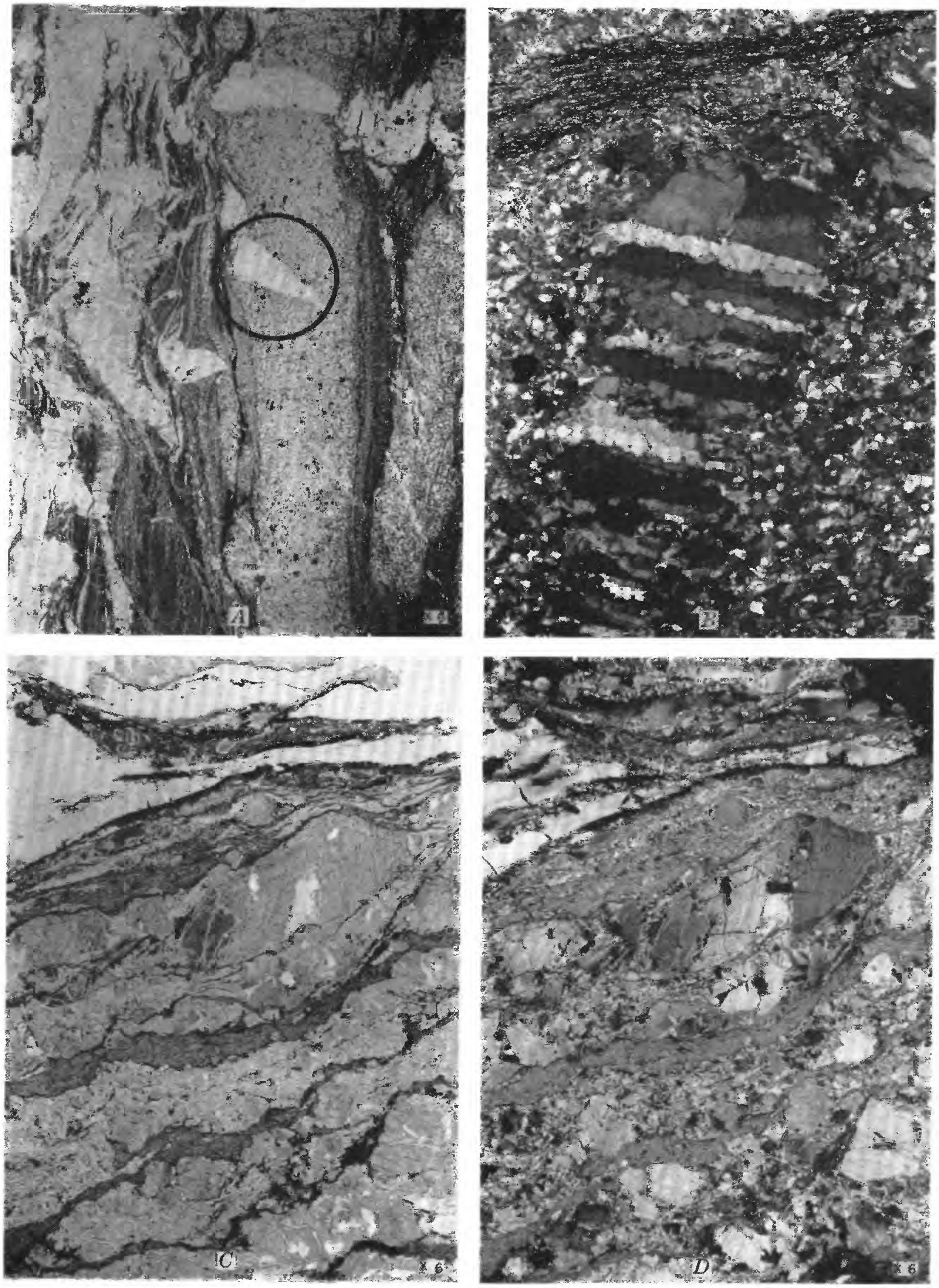
EXPLANATION OF PLATE 9

A, Open-cut made in mining manganese from weathered fault zone at the Dobbins mine. Quartzite and metashale of the Weisner formation in left wall strike obliquely against manganiferous clay, in bottom and right wall, that is residual from dolomite of the Rome formation.

B, Fault relation of white quartzite of the Weisner formation and dark baritic residuum of dolomite of the Rome formation in Section House mine.

C, Zone of plications ruptured to form fracture cleavage in unusually thin-layered amphibolite. The layers of the amphibolite dip away from the observer, the pitch of the plications is parallel to the dip, and the fracture cleavage is approximately vertical.

D, Layered porphyroblastic gneiss containing orthoclase crystals oriented diversely. Nonporphyroblastic layer, with gradational contact, is at bottom. Vein of bluish quartz, similar to that in groundmass, cuts porphyroblastic and nonporphyroblastic layers.


A
B
× 35
C
× 6
D
× 6

Paga No. 1 mine, in an outcrop 0.2 mile northwest of the Chulafinnee mine, and in an outcrop 0.5 mile northwest of the Bennett mine. Plate 12*B* shows the occurrence of the veins at the Paga No. 1 mine. A thin section of the vein material shows that the orthoclase is fractured and is veined with the quartz (pl. 12*C*) and that both minerals have been strained, as is shown by unevenly developed twinning in the orthoclase and strain shadows in the quartz. (See pl. 12*D*.) The relations of these minerals and their physical characters are the same as those of orthoclase and quartz in the porphyroblastic gneiss, indicating similar geologic history and therefore equal age.

What is perhaps the most significant occurrence of secondary orthoclase in the Cambrian rocks was observed in a ravine that drains northwest on Johnson Mountain, 1.2 miles north-northeast of Oak Hill Church. Closely adjacent outcrops on the southwest-facing slope expose about 70 feet of metashale and metasiltstone of the Conasauga formation; irregular parts of these rocks contain orthoclase porphyroblasts, which, in places, are so abundant that the rocks resemble the porphyroblastic gneiss. For a distance of 140 feet along the slope the porphyroblasts are most common in the upper part of the rocks exposed. In this part there are at least five bodies of fine- to medium-grained white rock similar to the oligoclase-mica gneiss except that mica laminae are very scarce and short. These bodies are thickly lenticular in the outcrops and appear tonguelike, pitching with the dip of the beds that enclose them. Their length in the plane normal to the dip ranges from 4 inches to 3 feet. The orthoclase porphyroblasts are most abundant near these bodies of white rock and form irregular aureoles around them; one of these associations is shown in plate 13*A*.

The white rock consists of orthoclase, oligoclase (An_{10}), quartz, and a very little zircon and sphene. It contains a few thin, sinuous laminae of muscovite approximately parallel to the bedding of the enclosing rocks. The orthoclase and quartz show, respectively, strongly developed strain twinning and strain shadows. They, and also the oligoclase, are fractured, but the oligoclase and the quartz fill fractures in the orthoclase and obviously crystallized later. The outcrops containing these bodies of white rock and the porphyroblasts are 5.5 miles from the nearest exposure of feldspathic gneiss, and the rocks elsewhere in the vicinity show no similar unusual features. Owing to their small size and apparent distance from any possible source of the constituent minerals, the bodies of white rock are believed to be pipe veins related in origin to the veins previously described. These pipe veins and associated porphyroblasts are interesting in four respects: first, the porphyroblasts are identical in character and distribution with those in the porphyroblastic gneiss; second, their occurrence in irregular aureoles around the pipe veins clearly indicates their immediate source; third, the porphyroblasts are not confined to the immediate contacts of the pipe veins; and fourth, the white rock of the pipe veins has essentially the same mineral composition as the orthoclase-rich variety of oligoclase-mica gneiss.

The positions of the pipe veins evidently indicate those of former channels along which new minerals were introduced into the metasediments to form the white rock and the associated porphyroblasts. The deposition of the porphyroblasts must have been related to the deposition or crystallization of orthoclase in the white rock. It may be inferred that the orthoclase sealed most of the minute openings in the wall rock, but only partly obstructed the channels, for oligoclase and quartz were later deposited in the channels. The scarce laminae of muscovite in the white rock appear to be remnant wisps of metashale. These may have been detached from the walls, or they may indicate that the channels were smaller than the pipe veins that were formed and that the minerals introduced along the channels partly replaced the immediate walls.

POSSIBILITY OF DYNAMIC EMPLACEMENT

It might be inferred that the feldspathic gneisses were emplaced by the forcible intrusion of igneous magmas. The foliate and layered structures might be interpreted as primary flow structures, or as having been induced by the deformation of originally massive rocks. Either interpretation must account for the presence of strong foliate and layered structures throughout the gneisses,

EXPLANATION OF PLATE 10

A, *B*, Photomicrographs of fine-grained metasiltstone from 1 mile southwest of Aubrey Lake. *A*, With plain light, showing wedge-shaped and irregular veinlets of orthoclase (white) and laminae of metashale (dark). *B*, With crossed nicols, showing veinlet outlined in *A*, enlarged. Note comblike structure of the orthoclase; quartz, in minor amount, has the same structure.

C, *D*, Photomicrographs of fluted porphyroblastic gneiss shown in plate 8*A*, *B*. *C*, With plain light, showing alternation of mica laminae and aggregates of the granular minerals. Note intricate veining of orthoclase (light gray) by quartz (white). *D*, With crossed nicols, showing most strongly fractured orthoclase (large crystals) and severely strained quartz (at top). Fine-grained material with orthoclase is largely quartz.

and not merely in their marginal parts.

The nature of the contacts does not support the interpretation of flow structure. The foliate and layered structures cannot be described as simply parallel to the walls; they are everywhere parallel to the bedding of the wall rocks, whether the contacts themselves are parallel, oblique, or transverse to the bedding. The same relation applies to contacts with the numerous inclusions of metasediments. The structure throughout the gneisses is also concordant with the prevailing attitude of bedding, and shows curvature only where there is corresponding curvature of bedding. The gneisses, therefore, show none of the structural patterns, independent either generally or locally of the structure of wall rocks and inclusions, that characterize igneous rocks with flow structure.[91] Their structural pattern faithfully reflects that of the rocks that enclose them.

Nor do contacts support the view that the foliate and layered structures in the gneisses were induced by the deformation of massive igneous rocks. The metasediments enclosing the gneisses and enclosed in them are mostly metashales, not interbedded with more competent metasediments in amounts sufficient to give an average competence even approaching that of massive igneous rock. If the metasediments and massive igneous rocks were compressed contemporaneously, the compressive force would be transmitted rather than absorbed by the igneous rocks, and would almost certainly develop in the adjacent weaker bedded rocks a strong flow or shear cleavage, which would obscure if not destroy their primary bedded structure. Even if the average competence of the bedded rocks became equal, through compression, to that of the massive rocks, permitting the massive rocks to be sheared, the orientation of the new foliate structure would be governed by regional compression; it would not show sensitive response to local curvature in the strike of the bedded rocks, such as that described and shown on the map. The curvature could be explained only by folding after shearing, but if this had occurred the intricate, concordant contacts between the flexible metashales and the more brittle gneisses could not have remained intact; they would have been torn in many places, resulting in discordant rather than concordant structural attitudes near the contacts.

The relations of the minerals, also, make it unlikely that foliate and layered structures were formed either by flowage or by deformation of igneous rock forcibly intruded. If the foliation and layering in the gneisses are interpreted as flow structures, the orthoclase porphyroblasts must be younger than the flowage, for they not only transect these structures but are intact even if factured; the segments of fractured crystals would have been separated during flowage if the orthoclase were older than the flowage. If the crystals were fractured after flowage, they must have been enclosed in a nonviscous matrix, but the chief minerals of the matrix are plagioclase and quartz, which are clearly younger than the orthoclase.

The fact is, however, that the effects of deformation are not obscured by recrystallization. The maximum effects shown are strain shadows, strain twinning, and simple fracture, without granulation or even appreciable displacement of crystal segments. The only alteration of the feldspars was sericitization along the fractures, and the sericite is entirely unlike, and not continuous with, the coarser-grained muscovite that forms the laminae. These features characterize feldspar crystals in the mica laminae as well as those outside, and the muscovite in the laminae cannot be attributed to the alteration of feldspar during the shearing of originally unfoliated rock. The feldspars and quartz clearly record successive crystallization under the influence of continuing deformation of mild to moderate intensity. If they were the constituents of originally unfoliated rock, they might show a sequence of crystallization, but not a sequence of deformation.

It is recognized that the layered gneisses, which include the andesine-augite gneiss and the irregular parts of the porphyroblastic gneiss having an andesine-augite groundmass, might be interpreted as originally an augite-biotite diorite. The possibility arises from the appearance of the nonporphyroblastic rock in hand specimen and thin section. (See pls. 6*D*, 7*A*.) The bodies of these layered gneisses could be regarded as sill-like, and their sharp layers as thin sills successively intruded, although there are no clearly intrusive dikelike bodies and no occurrences of the rocks beyond the margins of the porphyroblastic gneiss. The interpretation of the andesine-augite rock as diorite

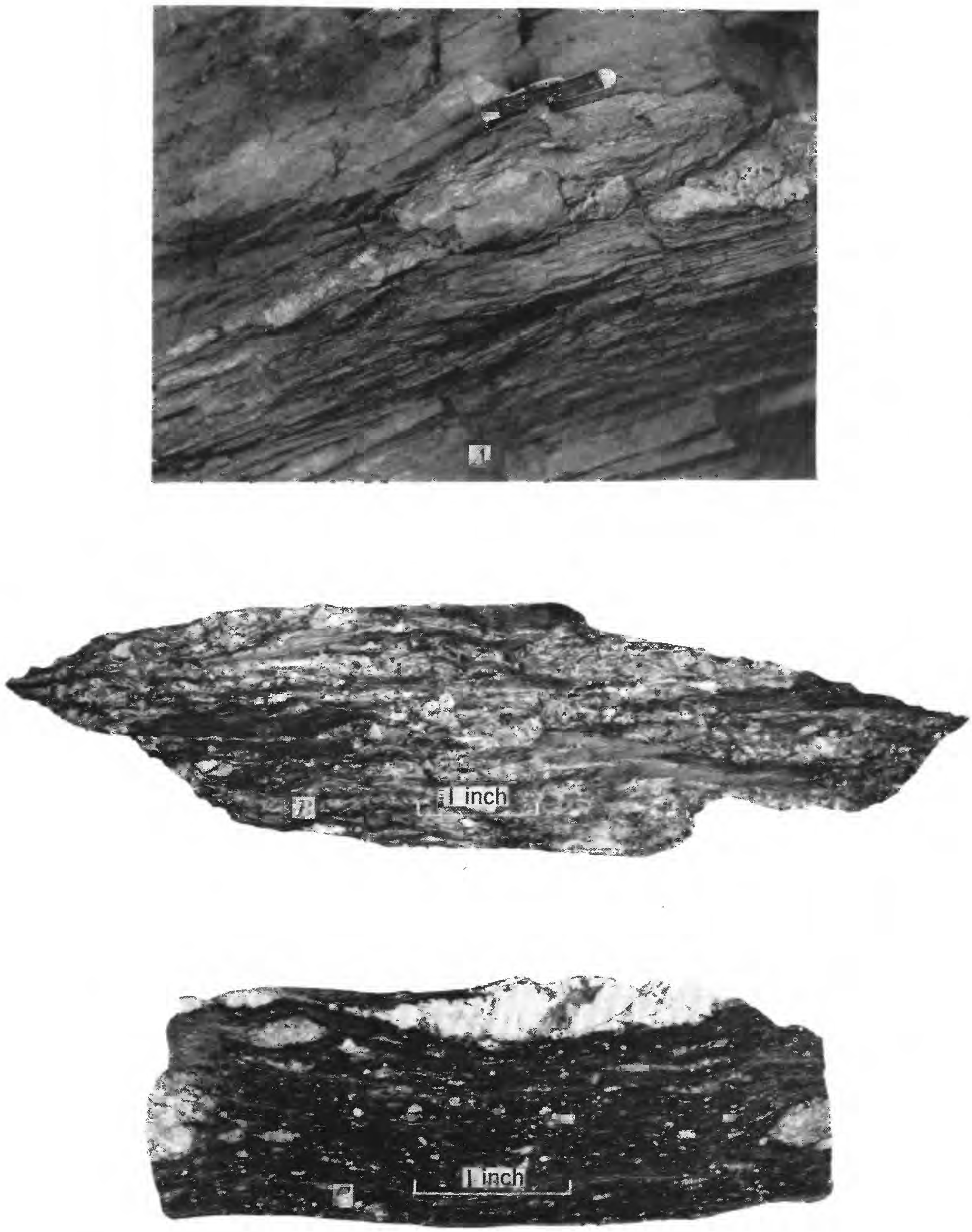
[91] Balk, Robert, Structural behavior of igneous rocks: Geol. Soc. America, Memoir 5, pp. 45-95, 1937.

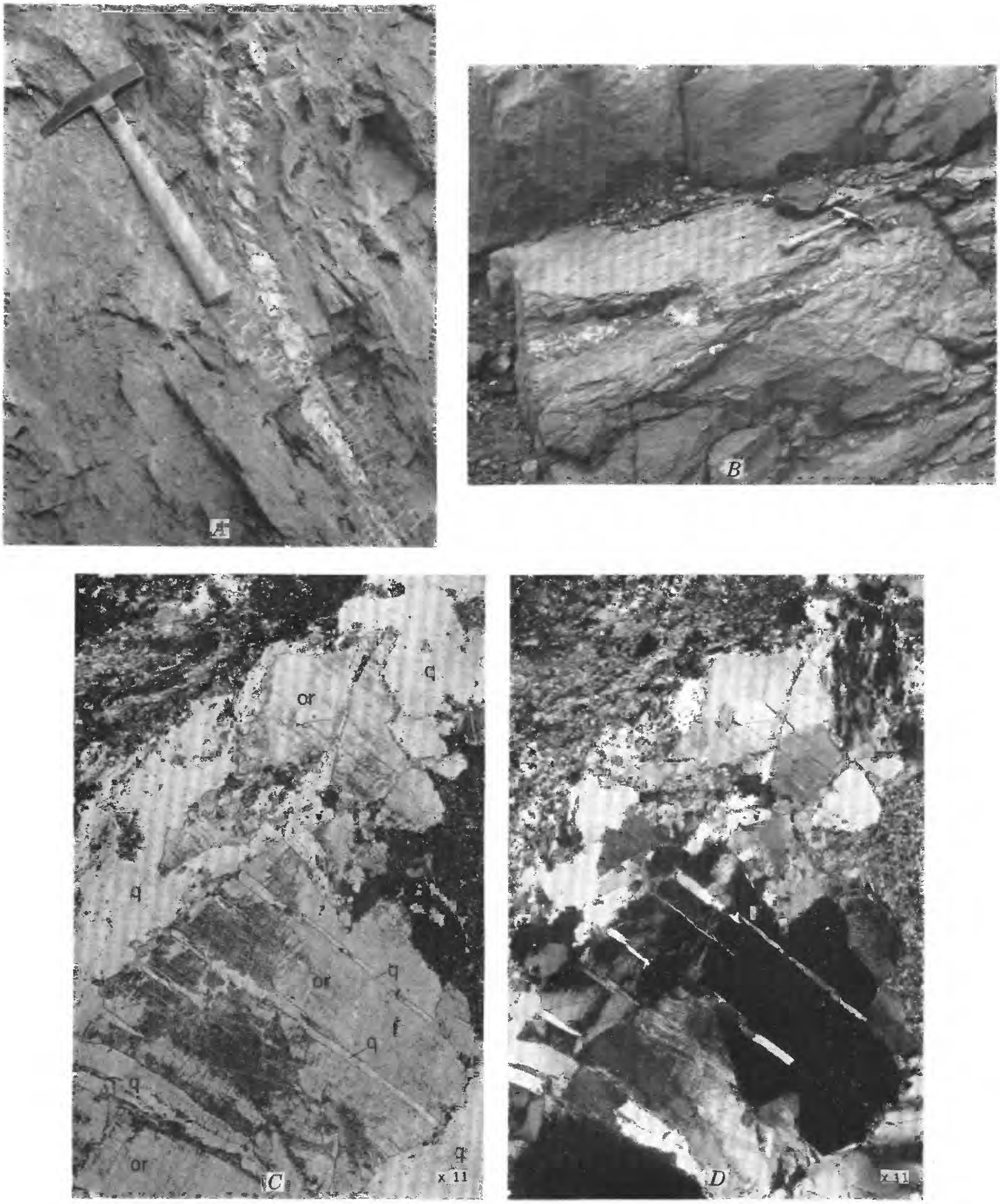
EXPLANATION OF PLATE 11

A, Crystals of orthoclase deposited in metashale of the Rome formation, 1.2 miles west of the Kelly mine.

B, Metashale of the Weisner formation containing porphyroblastic crystals of orthoclase, from crest of Hanging Mountain.

C, Metashale of the Weisner formation containing orthoclase in podlike crystals and aggregates, from outcrop 1.6 miles east of Stamp Creek Church.


A
B
1 inch
C
1 inch


A
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or
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C
x 11
D
x 11

would be based on its present mineral composition and texture, both of which are practically unmodified except for the quite variable uralitization of the augite. The rock could hardly have been intruded into the original Cambrian sediments without undergoing equivalent recrystallization, but even where the augite shows nearly complete alteration there is no corresponding alteration of the other minerals.

The feldspars present the most serious objection to the possibility of intrusive origin for these layered andesine-augite rocks. The orthoclase, both porphyroblastic and finer-grained, is the more fractured, and is corroded by the myrmekitic and non-myrmekitic andesine, which is by far the most abundant mineral in the rock. This relation shows that the andesine-augite gneiss is postorthoclase, or postporphyroblast, in emplacement or completion of development. If diorite had been intruded into the porphyroblastic gneiss, however, it might contain a few random porphyroblasts plucked from the wall rocks, but not in such amount and with such even distribution as characterize those in the porphyroblastic gneiss with andesine-augite groundmass.

It could be inferred that the curvature in the axis of the Weisner anticlinorium (see pp. 26-27) resulted from the forcible intrusion of magma, although it has been shown that the curvature may be accounted for by the uneven resistance to compression of the rocks to the west. The inference would necessarily involve the curvature only and not the folding, for the rocks are folded throughout the region and not merely where the gneisses occur. The faults that cut the folds of the anticlinorium appear to have been formed by rotational stress developed by unequal shortening. (See p. 28). If the stress were derived instead from the forcible intrusion of magma, it is reasonable to assume that the magma would have been forced into the faults, forming dikes. Even if the faulting occurred after the emplacement of the gneisses, it seems unlikely that such large bodies of magma could be forcibly intruded without any accompanying dikes. The minor bodies of secondary orthoclase and quartz in the Cambrian rocks clearly cannot be termed dikes, for they include isolated crystals and pods in unruptured rocks. It would seem likely, moreover, that if the gneisses were intrusive, the different kinds of gneiss were intruded at different times; and in that case one should cut another, whereas no such relation has been observed.

POSSIBILITY OF STATIC EMPLACEMENT

The preceding discussion has shown that there are serious objections to the hypothesis that the gneisses were dynamically emplaced as magma. The alternative possibility is static emplacement. This term, as used here implies that the gneisses may have been formed by the deposition of new minerals in older rocks rather than by intrusion. The implication is not restricted to any one of the processes generally termed recrystallization, replacement, and bed-by-bed injection. Grout,[92] in a systematic review of the literature, has shown that there is a marked lack of agreement and considerable ambiguity regarding the evidence interpreted to indicate these processes. The possibility of static emplacement is therefore discussed below only in relation to the evidence obtained in the present work, and with no inferences other than those which the evidence appears to warrant. The significant facts in evidence may be grouped as follows:

1. Near all of the intricate contacts, the invariable concordance of the foliation in the gneisses with the bedding in the wall rocks and inclusions, and the lack of deformation in the bedding, indicate a lack of rupture that argues against the action of force during or after emplacement. This relation strongly suggests that the present strike, dip, and relative position of the metasediments were acquired before the gneisses were formed.

2. The abrupt, uneven truncation of a large part of the Weisner rocks south of Pine Log Mountain shows that much of the eastern part of the Weisner anticlinorium is missing. The over-all width of outcrop of Weisner rocks south of the truncation, including the large bodies enclosed in the gneiss, reflects a normal southward plunge of the anticlinorium. The boundaries of the inclusions cannot be fitted into the western margin of the gneiss, and the inclusions in their present position lie within the original outline of the anticlinorium. The removal of a considerable part of this major structure, therefore, occurred without any lateral spreading of the rocks, and the attitude of the foliation between the inclusions and the truncated rocks

[92] Grout, F. F., Formation of igneous-looking rocks by metasomatism: a critical review and suggested research. Geol. Soc. America Bull., vol. 52, pp. 1525-1576, 1941.

EXPLANATION OF PLATE 12

A, Vein (below) and pods (above) of orthoclase deposited in shear zone in metashale of the Weisner formation.

B, Veins (near hammer and below, to right) of orthoclase, quartz, and calcite cutting dolomite of the Rome formation, exposed in the Paga No. 1 mine.

C, D, Photomicrographs of vein rock shown in *B*. *C*, With plain light, showing orthoclase, *or*, fractured and veined by quartz *q*. *D*, With crossed nicols, showing strain twinning in orthoclase and strain shadows in quartz.

to the north is the same as that which would be expected of the bedding in the Cambrian rocks that are missing.

3. Foliation, due to parallel mica laminae, is the predominant internal structure of the gneisses; metashale, consisting almost entirely of mica laminae, is the predominant rock of the metasediments. The crystals of orthoclase, which may be found individually and in podlike aggregates in the metashales, occur mostly between the laminae, but in places they cut the laminae, and they are clearly younger than the metashale. Similar coarse-grained orthoclase in the porphyroblastic gneiss has the same relation to the mica laminae in the gneiss. The intergradational contacts between metashale and porphyroblastic gneiss therefore strongly suggest that the mica laminae in the gneiss are residual laminae of metashale. Specimens of the Cambrian metashales highly impregnated with orthoclase crystals having a wide range in size, provide visible proof that mica laminae can be of residual origin.

4. Orthoclase, regardless of the size of its crystals, is, possibly excepting augite, the oldest of the nonmicaceous minerals in the gneisses. It is younger than its matrix, however, in the Cambrian metashales. The larger crystals are porphyroblastic in habit, like those in the metashales, and must have crystallized in an older matrix. The smaller crystals in all of the gneisses show the same paragenetic relations as the larger crystals, and merely reflect a wide range in the size of crystals of contemporaneous origin. If the older mica laminae are residual laminae of metashale, as seems likely, then metashale was the original matrix of orthoclase wherever the gneisses contain mica laminae. This would include the greater part of the porphyroblastic gneiss and all except the local hornblendic parts of the oligoclase-mica gneiss.

There is less direct evidence regarding the original matrix of the layered rocks, which include the andesine-augite gneiss and the irregular parts of the porphyroblastic gneiss with andesine-augite groundmass. It has been shown (see pp. 42-43) that there are reasonable objections to the possibility of an intrusive origin for these rocks, and that they were formed after the general deposition of orthoclase. The occurrence of augite of metamorphic origin in metasiltstone near the gneisses (see p. 37) provides definite evidence of an alternative origin. Metasiltstone occurs irregularly in all the Cambrian formations except the Shady; it normally contains magnesian carbonate, and its bedding is similar to the layering of the andesine-augite gneiss.

The occurrences of augite in the metasiltstone show that the agency that effected the deposition of the new minerals to form the gneisses also furnished sufficient heat to form augite in the Cambrian metasiltstones within its area of influence. The uralitization of the augite may then have occurred at somewhat lower temperature during the deposition of the later minerals, with subsequent mild chloritization of the uralite as a late-stage hydrothermal effect. The interpretation of the andesine-augite gneiss as strongly altered metasiltstone accounts for the seemingly incongruous relation of the feldspars, the apparent early origin and unique alteration of the augite, the structural accordance of the layered adesine-augite rocks with all associated rocks, and their irregular and widespread distribution—a distribution simillar to that of metasiltstone in the Cambrian formations.

The available evidence does not conflict with the the possibility of static emplacement of the feldspathic gneisses but rather favors it. The emplacement apparently began with the deposition of orthoclase in the Cambrian rocks, in greatest abundance in the area now underlain by the porphyroblastic gneiss, in smaller and irregular amounts in the areas now underlain by the other gneisses, and sporadically in very small amounts elsewhere. The orthoclase was irregularly strained and fractured; plagioclase and quartz were subsequently deposited with it, and were in turn strained and fractured. The amount and irregularity of the deformation is comparable with that in the quartzite (see p. 36), and may be similarly correlated with the irregular cessation of folding. At that time, the newly crystallized feldspars and quartz interferred with differential slip along the mica laminae in the foliated rocks most affected by the final movements and became somewhat deformed, but were better protected in the more competent layered rock.

The scope of the present work permits little speculation as to the possible relative importance of recrystallization, replacement, and bed-for-bed injection. The occurrence of secondary orthoclase in the metashales shows that parts of laminae in the metashales have been eliminated. This may account for the parallelism between laminae in the gneisses and metashales, near contacts, indicating that the laminae were not necessarily spread apart to make room for the other minerals. The alteration may have involved only a transfer of the chemical constituents of the muscovite and less abundant minerals of the rocks that were altered, although the occurrence of veins of orthoclase and quartz in dolomite of the Rome formation shows that the transfer could not have been confined to individual beds. The sporadic occurrence of the feldspars and quartz in the Cambrian metashales remote from the gneisses also shows that a watery solution must have effected at least a part of the alteration, for they occur in environments clearly inaccessible to a liquid of high viscosity.

Water or watery solutions abundant enough and hot enough to effect a static emplacement of the gneisses could have come only from a magmatic source. The distribution of the magma, in plan, must have been more or less similar to the distribution of the gneisses. The Carboniferous batholith beneath the Piedmont, which is believed to have furnished heat for the recrystallization of the Cambrian rocks (see pp. 37-38), could not have been the immediate source, for its influence was of wide extent, whereas the gneisses are of local occurrence although the bodies are large. It would seem logical, however, to infer that any stocks intruded to higher levels from the batholith would have had, on adjacent rocks, an influence much stronger than the regional influence of the more distant main body. The agents of the stronger influence would have been hydrous emanations expelled from the stocks into the adjacent rocks. The likely importance of this influence on rocks overlying granitic bodies has been pointed out by Barrell,[93] and later by Gilluly[94] who showed that deep granitic magma may contain as much as 8 percent of water, an amount believed to be adequate for far-reaching effects.

All the evidence obtained in the present work indicates that the gneisses must be underlain at comparatively shallow depth by granitic bodies, and the broad structural features of the district suggest an explanation for the localization of these bodies. The Weisner anticlinorium would have provided an arched structure favorable for the intrusion of a stock, and its axis, moreover, is inclined eastward toward the batholith inferred; the eastern limb of this anticlinorium, which directly overlies the logical path of intrusion, contains the gneisses in the east-central part of the district. The gneiss in the southeastern part occurs east of the synclinorium described on pages 33-35; the structure in that area appears to be anticlinorial, and therefore also favorable for the intrusion of a stock.

DEPOSITION OF PRIMARY ORE AND GANGUE MINERALS

OCCURRENCE OF THE MINERALS

SULFIDES

The sulfides in the Cartersville district that are not formed by weathering but instead are destroyed by it include pyrite, galena, sphalerite, chalcopyrite, enargite, and tennantite. All except pyrite are restricted to carbonate rocks, and to the less weathered parts of their residuum, but pyrite is widely and unevenly distributed in rocks of all types. All the sulfides except enargite have been found enclosed in barite residual from the weathering of carbonate rocks, as well as elsewhere, but none have been seen to vein the barite.

Pyrite.—The least-weathered waste on some of the dumps at the brown-ore mines includes masses of fine-grained pyrite and of jasperoid containing abundant similar pyrite. The material examined shows all stages in the alteration of the pyrite to limonite. Such pyritic waste has been found at the Sugar Hill, Black Bank, Conner, Norris, Convict, and Iron Hill mines, and at four smaller, unnamed workings. In some of the material, pyrite forms the matrix of breccia. (See pl. 14*A* and page 85.) At the Black Bank mine, a knob of the pyrite was left in place, projecting from the bottom of the largest open-cut, as shown in plate 14*B*. A specimen of this pyrite tested weakly positive for vanadium, but other specimens, collected at other mines, tested negative.[95] Nine samples of pyrite from different mines, one of them containing a little enargite and tennantite, showed 0.01 to 0.12 percent of MnO.[96]

At the Sugar Hill, Big Mountain, Wildcat Hollow, and Bartow No. 3 mines, Weisner quartzite beneath and adjacent to the brown-ore deposits is impregnated with pyrite. Pyrite is also irregularly distributed in the veins of orthoclase and quartz described on pages 40-41, as well as in the rocks that enclose them, and it occurs in quartz veins that cut the specular-hematite beds at the Bartow Mountain mine.

Pyrite occurs persistently with the other sulfides and with barite. It is characteristically present in barite, in small amounts, and occurs chiefly near the contact with dolomite and near the margin of masses of the barite in residual clay. Incrustations of pyrite occur also in rare small vugs in jasperoid. (See p. 50.)

Galena and sphalerite.—The lead and zinc sulfides have been found together in barite from the Iron Hill and Tucker Hollow mines. The occurrence of galena in barite has been reported previously.[97] Both minerals are rarely coarse-grained enough to be identified with the hand lens. (See pl. 15*A*.) They are commonly associated with pyrite, chalcopyrite, and tennantite, which are also enclosed in the barite. A little of the galena is enclosed in the sphalerite, but there is no other evidence to indicate

[93] Barrell, Joseph, Relations of subjacent igneous invasion to regional metamorphism: Am. Jour. Sci., 5th ser., vol. 1, pp. 2-19, 1921.

[94] Gilluly, James, The water content of magmas: Am. Jour. Sci., 5th ser., vol. 33, pp. 436-441, 1937.

[95] Spectrographic analyses by George Steiger.

[96] Chemical analyses by Michael Fleischer.

[97] Little, George, Report of progress of the mineralogical, geological, and physical survey of the State of Georgia, for 1874, p. 12, Atlanta, Ga., 1875.

the paragenesis of the sulfides or their relation to the barite. Minute selvages of cerussite, formed by weathering, occur along the margins of the galena.

Chalcopyrite.—The rarest of the sulfides that occur in barite is chalcopyrite. It has been identified in barite from the Tucker Hollow mine (see pl. 15*A*, and Hull[98] reported its occurrence in barite from the Section House mine.

Chalcopyrite occurs also at two localities in the extreme northern part of the district. One of these is on United States Highway No. 411, immediately north of the Pine Log Creek bridge, where dark-blue dolomite, fractured and unevenly silicified, contains chalcopyrite and tennantite. The other locality is on the south bank of Sugar Hill Creek, 0.4 mile northeast of Fairview Church, where dark-gray dolomite is cut by a narrow vein of quartz and dolomite. The vein, which has been prospected, contains a little chalcopyrite that encloses enargite, as shown in plate 15*B*. These deposits are described more fully on page 92.

Enargite and tennantite.—Sulfides of copper and arsenic occur together with pyrite in nearly fresh residual jasperoid and vein quartz at the Aubrey manganese mine. The tennantite encloses smaller masses of luzonite, the pink variety of enargite and has been altered marginally to chalcocite by the action of weathering. (See pl. 15*C*, *D*.) The chalcocite shows granular structure, without cleavage, after treatment with nitric acid.

As previously stated, gray enargite and tennantite are associated with chalcopyrite in veins in the northern part of the district. Tennantite has also been identified in barite from the Reservoir Hill and Tucker Hollow mines. Its mode of occurrence in the barite is similar to that in the jasperoid at the Aubrey mine.

SPECULARITE

The nature and occurrence of specularite, in beds in the Shady formation, have been described on pages 10-11. Elsewhere it occurs in minute amounts in a few joints and narrow shear zones in quartzite of the Weisner formation, and also in rare small vugs in jasperoid. The vugs are described on page 50.

QUARTZ

There are two distinct generations of the quartz associated with the mineral deposits. The quartz of the first generation is coarse-grained, glassy, and colorless to milky white. It sporadically accompanies all the primary ore minerals, and it occurs alone in veins cutting all types of the country rocks, in veins with calcite and dolomite cutting carbonate rocks, and in clusters of terminated crystals in the weathered residuum of carbonate rocks. The clusters apparently developed in vugs in the quartz-carbonate veins, although none have been seen in place.

The quartz of the second generation is much more abundant and was deposited after the primary ore minerals. This variety is jasperoid, which is described separately below.

CARBONATES

Coarse-grained calcite occurs commonly in veins that cut the carbonate rocks of the Rome formation. A few of the veins contain coarse-grained dolomite instead of calcite. The calcite-bearing veins commonly contain quartz and pyrite, and less commonly chalcopyrite, enargite, and orthoclase.

The reported occurrence of iron carbonate in the Sugar Hill iron mines[99] could not be verified in the present study, although the dumps were examined with considerable care. It seems likely, however, that siderite was deposited contemporaneously with the other vein carbonates. The only iron-bearing carbonate found in the present study is ankerite, which occurs in scarce veins, with a little pyrite, in the Weisner rocks on the Etowah River near the Allatoona dam site.

BARITE

The carbonate rocks of the Rome formation in places contain veins and irregular bodies of coarsely crystalline barite, but the relative scarcity of outcrops of these rocks makes it impossible to determine the abundance and trends of such veins. The barite occurs in aggregates of anhedral, tabular crystals, which are commonly curved. The individual crystals are transparent, but the aggregates are white. The barite is accompanied by vein quartz and carbonates, and encloses sulfides as already described.

The veins have been observed in pinnacles and residual masses of the bedrock in a small open cut 800 feet east of the Tucker Hollow mine, in another 900 feet northwest of the Paga No. 2 mine, in the Section House mine, and in outcrops of dolomite on the Etowah River at the plant of Thompson-Weinman and Co. The veins observed are mostly less than 2 inches thick. The irregular bodies are thicker (See pl. 14*C*); those seen are not more than 6 inches across, but a residual mass taken from the Tucker Hollow mine in 1941 was 4 feet across. (See pl. 14*D*.)

Barite veins apparently occur also in the dolomite beds in the underlying Shady formation, although the beds are not exposed. Shady fossils replaced by

[98] Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, p. 56, 1920.

[99] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, pp. 19, 162-163, 1900. Catlett, Charles, Discussion in Am. Inst. Min. Eng. Bi-monthly Bull. 24, pp. 1179-1183, 1908.

barite have been collected from the weathered residuum of Shady rocks at the Hurricane Hollow, Barium Reduction, New Riverside, and Nulsen mines. These fossils make it evident that barite was deposited by replacement as well as in fissures.

A deposit of barite similar to that in the carbonate rocks occurs in the porphyroblastic gneiss, 100 feet east of the contact with Weisner rocks, on the east side of Pine Mountain. The location of the deposit is shown on the geologic map. The barite occurs in nearly vertical thin veins cutting the foliation of the gneiss, and in lenticular masses as much as 4 inches thick and 8 inches long oriented parallel with the foliation. It encloses residual orthoclase, quartz, and mica laminae, and contains pyrite.

The jasperoid, described below, in many places contains barite of different habit. The barite crystals, which are colorless and transparent, are not curved and do not have terminal faces. They occur in both fresh and weathered jasperoid, and are commonly removed by weathering, leaving thin, tabular cavities. In the area between Emerson and Pumpkinvine Creek, the tabular crystals are sufficiently abundant in places in the jasperoid to attract prospecting. The most important of the deposits is described on pages 89, 91, but none of them have been developed successfully as have the deposits of white barite residual from the carbonate rocks. Watson[1] published an analysis of a composite sample of "Weisner quartzite" showing 4.46 percent $BaSO_4$, but his geologic descriptions show clearly that he did not distinguish quartzite from jasperoid. It is probable that the barium sulfate shown by his analysis was derived from baritic jasperoid, such as that described here, included with samples of quartzite. The only primary barite observed in place by the writer, in any rocks other than dolomite of the Rome formation, jasperoid, and porphyroblastic gneiss, occurs in minute amount in thin sections cut from drill cores of Weisner rocks at the Allatoona dam site. It is contained in a calcite veinlet in dolomitic limestone and in a quartz veinlet in calcareous metasiltstone.

STRENGITE

Analyses of the manganese and iron oxide ores invariably show a rather low and uneven content of phosphorus. The only phosphate mineral found in close association with any ore deposit is strengite (hydrous iron phosphate), collected at the Iron Hill brown-ore mine. The strengite occurs as a tabular mass, 0.3 inch thick, composed of radial clusters of finely acicular crystals. Limonite, which is attached to the mass, permeates and is of later origin than the strengite. It appears from the shape of the mass that the strengite was deposited on the wall of a fissure or cavity. As the limonite is a supergene mineral formed from the weathering of pyrite, the strengite probably was deposited as a primary, late-stage gangue mineral under conditions of low temperature and excess water. The geologic associations of the Iron Hill brown ore are similar to those of brown ore and manganese in other parts of the district, and strengite and related phosphates are probably the source of the phosphorus in these ores at all the mines.

[1] Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, p. 15, 1906.

NATURE AND OCCURRENCE OF THE ASSOCIATED JASPEROID

The clays residual from the weathering of carbonate rocks of the Rome formation in many places contain irregularly distributed masses of a fine-grained quartz rock from 1 inch to 20 feet across. These masses have uneven but smooth outlines. Most of the rock is weathered and strongly stained throughout by ferric hydroxide, but some is lightly stained, and a very little is white. The same variety of quartz rock occurs in the residuum of dolomite, interbedded with hematite, in the Shady formation and contains fossils similar to those in the hematite. These fossiliferous boulders have been found in the residuum of the Shady rocks at the Paga No. 1, Winterbottom, Georgia Peruvian, Roan, Howard, and Dobbins mines, and at nine other localities.

On the geologic map made by Hayes[2], who regarded the quartz rock as quartzite, the Weisner formation is shown in areas in which this rock is especially abundant. This interpretation persisted in most subsequent geologic work, but LaForge[3] and Hull[4] recognized a difference between the quartz rock and quartzite, although they did not use it as a criterion in mapping. Each referred to the quartz rock as chert or chertlike, and noted that it occurs only in the residuum of carbonate rocks. The quartz rock is termed jasperoid in this report, and its abundance, localization, and common association with economic mineral deposits require a full discussion of its nature and origin.

The unweathered jasperoid is light to dark gray and is much finer-grained than any quartzite in the district. It has a dull appearance, in contrast to the vitreous luster of fresh quartzite. In thin section, the jasperoid is seen to consist of minute, anhedral, interlocking grains of quartz. The jasperoid weathers more rapidly than quartzite, and disintegrates into ocherous to white, powdery quartz. Strongly weathered jasperoid is porous and friable,

[2] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Am. Isnt. Min. Eng. Trans., vol. 30, p. 405, 1901.

[3] LaForge, Laurence, The Cartersville district, in Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, p. 45, 1919.

[4] Hull, J. P. D., op. cit., p. 26.

and is coated with minute terminated quartz crystals of supergene origin; the fresh rock contains no terminated crystals.

A little of the jasperoid is thinly bedded and is commonly dense, almost chalcedonic, in appearance. Most of it is not bedded and is coarser-grained than the bedded variety. Jasperoid of both varieties is most abundant in areas adjacent to the faults shown on the geologic map, but it may be found in large amount also in limited areas where there are not enough outcrops to afford a basis for structural interpretation. The jasperoid is not restricted to the residuum of any stratigraphic part of the carbonate rocks, and its abundance in the district diminishes from east to west. The areas in which it is most abundant are shown on the geologic map.

The coarser-grained, massive jasperoid in many places contains angular fragments of the finer-grained jasperoid, and less commonly fragments of vein quartz. It is unusually abundant in a well-exposed fault zone at the Paga No. 1 mine, where it contains brecciated barite like that in the dolomite nearby. (See pl. 13*B*.) Unweathered jasperoid sporadically contains pyrite, chalcopyrite, tennanite, and enargite, but the sulfides are not found in weathered jasperoid. The pyrite occurs in disseminated grains and in aggregates mostly in the massive jasperoid at the brown-ore mines. Pyrite, tennantite, and enargite occur in massive jasperoid at the Aubrey mine. (See p. 46; pl. 15*C*, *D*.) A significant occurrence of chalcopyrite and tennantite in dense jasperoid is described farther in this section.

Some of the dolomite of the Rome formation, at mines in which jasperoid is abundant, contains fine-grained quartz similar to that in the jasperoid. Plate 13*C* shows a photomicrograph of quartzose dolomite from a pinnacle in the Paga No. 1 mine. The dolomite is fresh; it contains unoxidized pyrite and has no open seams or solution cavities. The quartz occurs in ragged, anastomosing veinlets containing a little coarse carbonate, which cut the rock in all directions. It obviously is not detrital and is of later origin than the dolomite, for the rock matrix is divided into residual bodies by the abundance and thickness of the veinlets. As the bedding is undisturbed, the quartz could not have been deposited entirely in open fissures but must have replaced the dolomite along the walls of minute fractures. The lack of solution and oxidation indicates that the quartz was not deposited by ground water. Quartz of similar habit is present also in core-drill samples of fresh carbonate rocks of the Weisner formation taken from various depths down to 131 feet below the bed of the Etowah River at the Allatoona dam site.

Jasperoid is exposed in place in fresh dark-blue dolomite where United States Highway No. 411 crosses Pine Log Creek. Part of the dolomite is strongly fractured, and the fractures contain vein quartz and a little chalcopyrite and tennantite. Some of the dolomite adjacent to the fractures has been converted to jasperoid, which is dense, nearly black, and unweathered. The sulfide veinlets nearest the surface contain films of supergene azurite and malachite, but these films cut dolomite, jasperoid, and sulfides alike and are obviously of later origin, having been formed by infiltrated surface waters. Carbonate rocks exposed elsewhere in the vicinity do not contain sulfides or jasperoid, although they are as accessible to ground water as the rock here described. The evidence is conclusive that the partial silicification of the dolomite is related to the deposition of the primary ore minerals in the zone of fracture rather than to weathering and the deposition of the supergene minerals.

As pointed out above, the unweathered carbonate rocks in places contain nondetrital quartz of later origin than the carbonate minerals. Conversely, the jasperoid in places contains a carbonate mineral that occurs in residual grains of microscopic size enclosed in unfractured grains of the quartz. The residual grains are rounded, as by corrosion, and are evidently of earlier origin than the quartz.

A thin section cut from massive jasperoid from the Dobbins mine shows well-preserved carbonate cleavage throughout (see pl. 13*D*), as well as a texture that is coarser than that of the dolomite and limestone. The texture and cleavage are emphasized by iron oxide introduced during weathering. The jasperoid is of the coarser abundant variety that lacks bedded structure. It contains no carbonate mineral and consists of fine-grained quartz like that in the dolomite shown in plate 13*C*.

The evidence provided by this thin section is important, for it shows that the massive jasperoid was formed by the replacement of vein carbonate and therefore accounts for the absence of bedded

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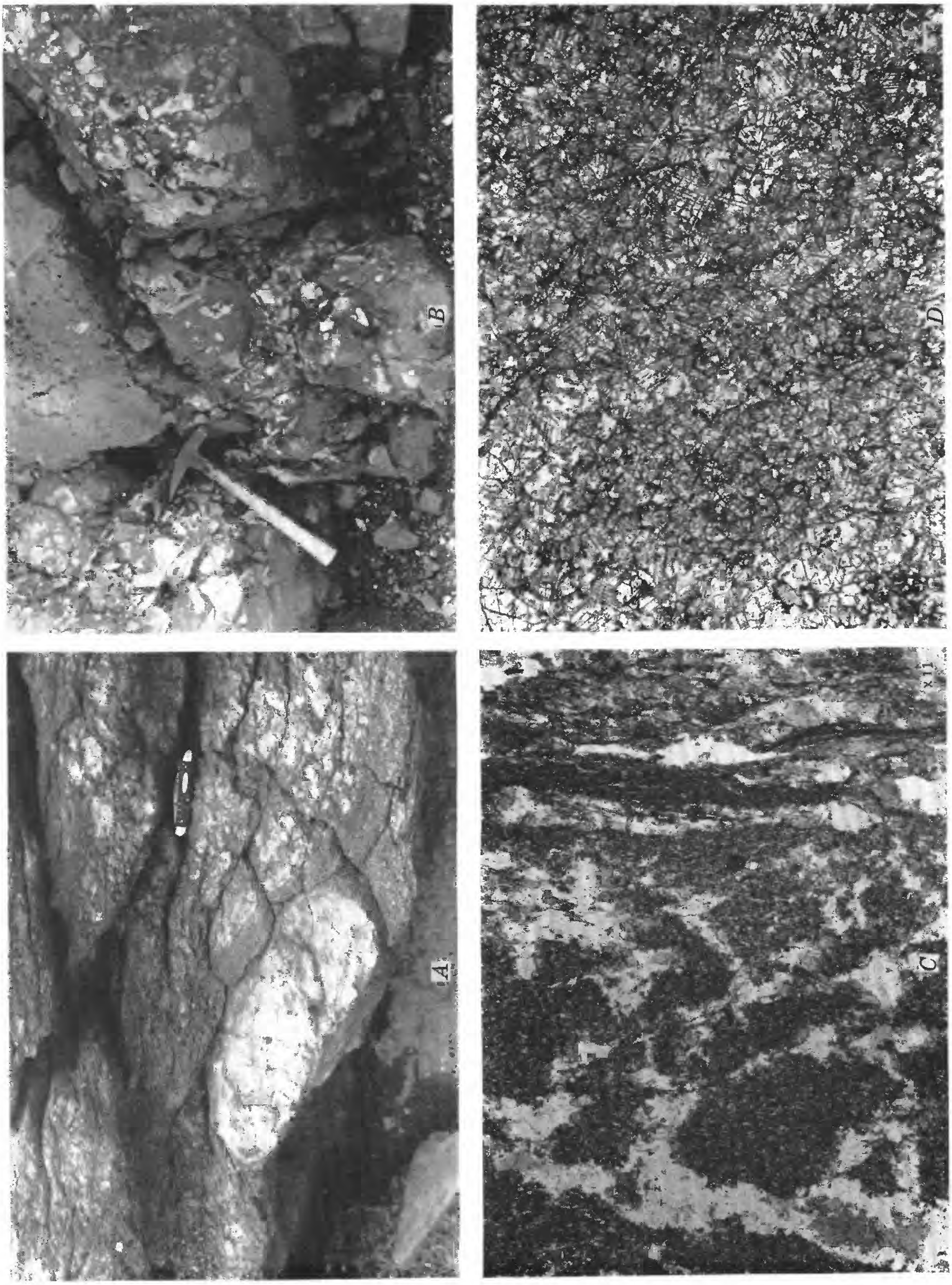
EXPLANATION OF PLATE 13

A, Metasiltstone of the Conasauga formation containing orthoclase porphyroblasts.
B, Brecciated barite, enclosed in massive jasperoid in fault zone at the Paga No. 1 mine.
C, Photomicrograph showing dolomite of the Rome formation (dark granular areas) partly replaced by fine-grained quartz (white) containing a little coarse carbonate (gray). Black cube is unweathered pyrite. With plain light.
D, Photomicrograph of jasperoid from the Dobbins mine, showing well-preserved carbonate cleavage and texture. With plain light.


B
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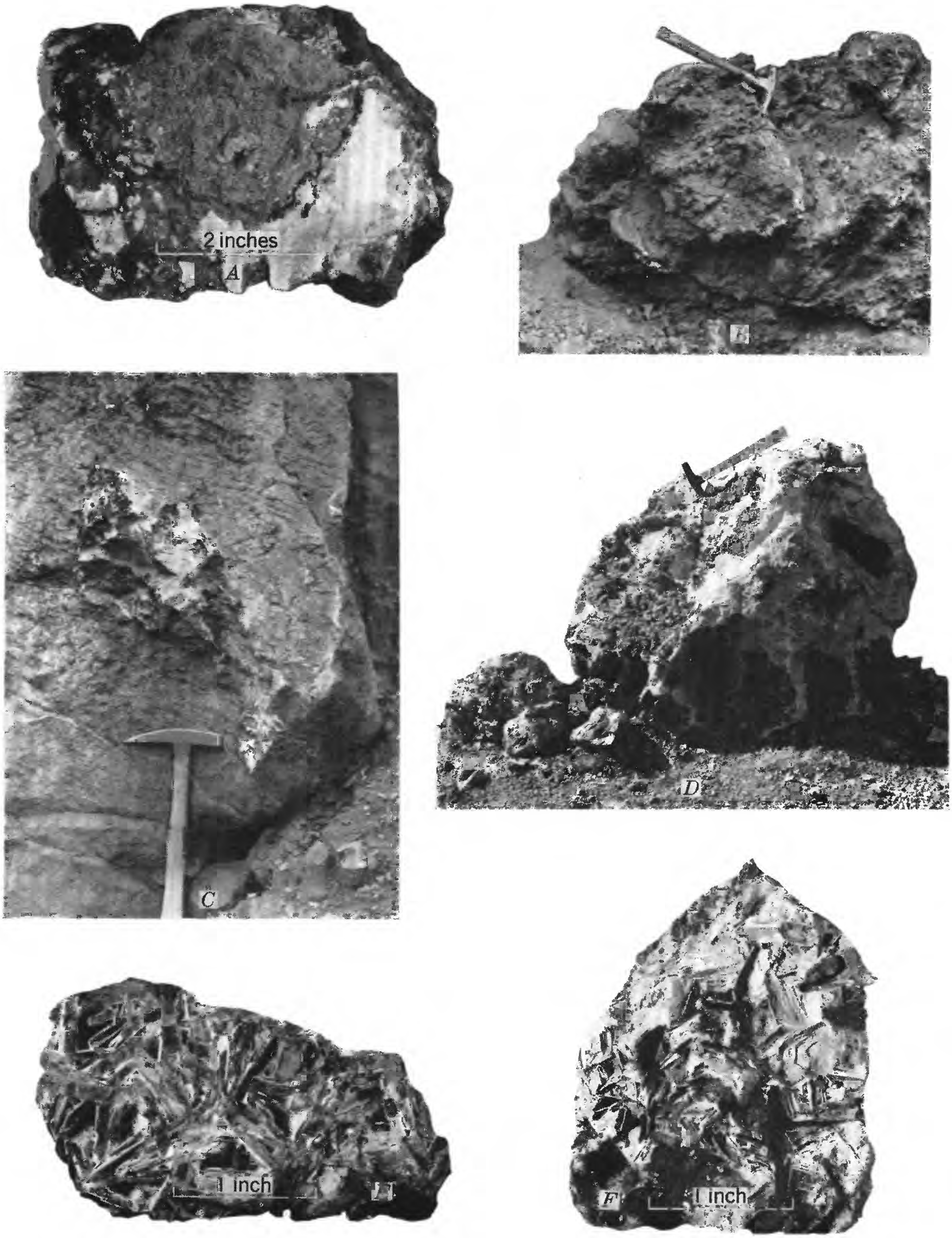

2 inches
A
C
D
1 inch
F
1 inch

structure in that rock. As the same variety of jasperoid at the Paga No. 1 mine encloses angular masses of the denser jasperoid, of barite, and of vein quartz, it is clear that silicification in places occurred in earlier, mineralized fault zones. The bedded structure of the denser jasperoid is similar to that of the carbonate rocks, and this variety must have been formed by the replacement of parts of the wall rocks, including brecciated masses detached from them.

In summary, the jasperoid may be found only in areas underlain by carbonate rocks. It is restricted to fault and fracture zones wherever the structure of the bedrock is evident. Some of the carbonate rocks underlying such areas contain fine-grained quartz similar to that in the jasperoid; this quartz is not detrital and was not deposited by ground water. The fresh jasperoid commonly contains sulfides, which are known to be unstable in ground-water environment. Some of the jasperoid contains residual carbonate grains enclosed in unfractured quartz grains. The coarser jasperoid clearly consists of quartz that has replaced vein carbonate, and in places it encloses angular masses of the denser jasperoid, of barite, and of vein quartz. The bedded structure of the denser jasperoid is similar to that of the carbonate bedrock, and the angular masses are apparently quartz-replaced breccia fragments of the carbonate rocks.

TIME AND MODE OF DEPOSITION OF THE MINERALS AND JASPEROID

The bedded specular hematite in the Shady formation apparently differs radically in origin from the other primary ore minerals. Since it occurs only in certain strata and is absent from the vein deposits, it cannot be regarded as epigenetic. The mineral is destroyed by weathering, however, and could not have survived the erosion essential for deposition in clastic beds.

The hematite ore is a metamorphic rock, and its origin must correspond with that of the other rocks with which it is associated. The specularite was evidently formed by the recrystallization of a sedimentary, iron-rich mineral that was originally distributed unevenly through the sedimentary rock. Hayes and Eckel[5] have suggested that the original mineral may have been a carbonate, a hydrous oxide, or a sulfide. Pyrite occurs in quartz veins that cut the ore and is therefore younger than the hematite. The fossils and oolites that the ore contains here and there consist entirely of specularite and are enclosed in fine-grained quartz. This relation is similar to that of amorphous red hematite and calcite in the Clinton iron ore, of Silurian age, and the similarity suggests that the original iron mineral may have been amorphous hematite. The original matrix of the hematite may have been calcite which was replaced by quartz, for parts of the associated dolomite were silicified, forming jasperoid.

All the primary ore and gangue minerals other than the specularite may be found in rocks that have been fractured. Owing to the deep-reaching destructive effects of weathering, these minerals are not exposed in abundance; they occur mostly in the less-weathered parts of the secondary mineral deposits, as described farther on in this report. Most of these deposits are adjacent to faults, as shown on the geologic map, and the fracturing of bedrock was evidently associated with faulting. The primary ore and gangue minerals were therefore deposited after faulting and before weathering, for all of them, including jasperoid, are destroyed or modified by weathering. They make up a typical hydrothermal assemblage and must have been deposited by solutions that moved upward, along the faults, from depth.

The faulting occurred near the close of folding (see p. 28) and the occurrence of brecciated barite enclosed in jasperoid shows that there was renewed movement along some of the faults after the barite had been deposited, and before the jasperoid had been deposited. The sulfides and barite appear to have been deposited contemporaneously and were preceded and accompanied by vein quartz and carbonates. Some of the early deposits were brecciated by subsequent movements, and a second wave of solutions deposited large amounts of quartz, which replaced vein carbonates, parts of the car-

[5] Hayes, C. W. and Eckel, E. C., Iron ores of the Cartersville district, Georgia, in Contributions to economic geology, 1902: U. S. Geol. Survey Bull. 213, p. 238, 1903.

EXPLANATION OF PLATE 14

A, Pyritic breccia from residuum of dolomite of the Rome formation at Sugar Hill brown-ore mine. Matrix is pyrite partly altered to limonite; fragments consist of jasperoid (left side) and vein quartz (right side).

B, Knob of massive, fine-grained pyrite in place in the Black Bank brown-ore mine.

C, Lenticular body of barite in dolomite of the Rome formation, exposed by barite mining 900 feet northwest of the Paga No. 2 mine.

D, Residual mass of barite, 4 feet across, recovered from residuum of dolomite of the Rome formation at the Tucker Hollow mine.

E, Tabular barite crystals coated with fine-grained supergene quartz.

F, Quartz coatings left after the removal of barite by weathering.

bonate wall rocks, and breccia fragments of the wall rocks. The quartz rock thus formed is the jasperoid, and its occurrence in great abundance in restricted localities, with and apart from the deposits of ore minerals, shows that new faults were formed contemporaneously with further movement along those in which the ore minerals had been deposited.

The clear, tabular barite in the jasperoid (see p. 47), which is unlike the brecciated white barite, was introduced with the jasperoid. The jasperoid that encloses the tabular barite also contains rare small vugs, and the tabular barite commonly coats their walls. The barite is incrusted with tiny hexagonal plates of hematite and with finely granular pyrite, which are evidently younger than the same minerals in the other environments previously described. The hematite and pyrite were apparently deposited at the close of jasperoid deposition, possibly from constituents concentrated by the deposition of the quartz and tabular barite. The chemical constituents of the tabular barite and the hematite and pyrite in the vugs may have been derived from earlier deposits of the same minerals through which the solutions that deposited the jasperoid passed.

EROSIONAL HISTORY

Younger Paleozoic rocks were undoubtedly deposited on and folded with the Cambrian rocks that are now exposed, but the younger rocks have been removed by post-Carboniferous erosion. Although the total relief in the district is 1,640 feet, the altitudes of most of the surface lie within two narrow intervals, one ranging from 800 to 900 feet, the other from 1,000 to 1,100 feet. The very uneven distribution of altitude reflects uneven degradation, and the predominant intervals record base-leveling by early streams and the consequent development of peneplains or surfaces of low relief.

LaForge[6] has correlated surface altitudes in the Cartersville district with altitudes that characterize peneplains in other parts of the Southern Appalachian region. He regarded the summits of some hills and ridges 1,300 to 1,400 feet in altitude as remnants of the oldest and highest peneplain, the Cumberland, which he believed was formed in Jurassic time. He correlated the Piedmont upland in the east and isolated ridges in the west, whose altitude is 1,000 to 1,100 feet, with the Highland Rim peneplain, which he considered to be of Cretaceous age. He regarded the lowlands in the west, whose average altitude is 800 to 900 feet, as the incompletely developed Coosa peneplain, or terrace, to which he assigned a Tertiary age.

Fenneman,[7] in a comprehensive review and discussion of the literature, points out that there is a wide and, at present, irreconcilable range of opinion on the age and correlation of peneplains in the Piedmont and Appalachian Valley provinces. The ages assigned by LaForge are undoubtedly the maxima warranted by the evidence, and the peneplains may be considerably younger. The evidence is derived from broad geologic relations throughout the Appalachian region as a whole, and the relations shown in the Cartersville district merely harmonize with the known succession of the peneplains.

The Cumberland peneplain cannot be recognized in the district, for there is no uniform altitude of ridges and hills at the interval assigned to that peneplain by LaForge. If the Cumberland peneplain was developed in this region, it was subsequently destroyed by the cycle or cycles[8] of erosion that formed the Piedmont Plateau, or Highland Rim peneplain.

The topography in plate 1 shows that the Highland Rim and Coosa levels are strongly developed, and the geology shows the influence of lithology on their preservation. The eastern part of the district is largely underlain by noncalcareous rocks that are more or less uniformly resistant to weathering. The western part, however, is underlain by calcareous and noncalcareous rocks differing widely in resistance to weathering. The Highland Rim peneplain was developed throughout the district, except in the ridge belt, which persisted as a series of monadnocks. During the development of the Coosa terrace, the Highland Rim level was destroyed only in areas underlain by calcareous rocks, and hence the uneven surface in the western part of the district.

Erosion was vigorous during the development of the Highland Rim peneplain, and again during its dissection, but was sluggish in the intervening

[6] LaForge, Laurence, The Cartersville district, in Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 63-64, 1919.

[7] Fenneman, N. M., Physiography of Eastern United States, 1st ed., pp. 121-162, 195-278, 1938.

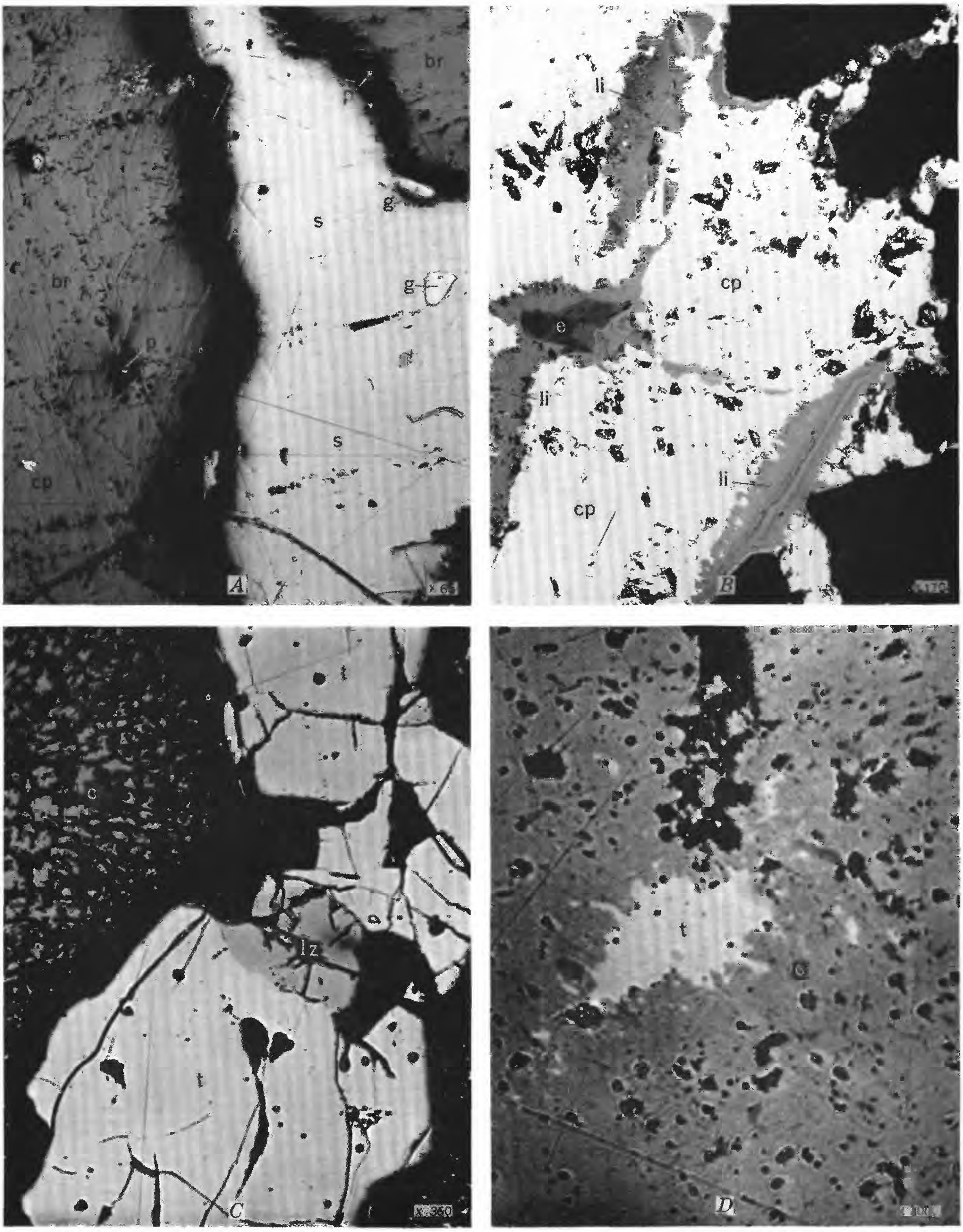
[8] LaForge, Laurence, The central upland, in LaForge, Laurence, Cooke, C. W., Keith, Arthur, and Campbell, Marius, Physical geography of Georgia: Georgia Geol. Survey Bull. 42, pp. 90-91, 1925.

EXPLANATION OF PLATE 15

A, Photomicrograph of barite, *br*, enclosing galena, *g*; sphalerite, *s*; pyrite, *p*; and chalcopyrite, *cp*. Specimen from the Tucker Hollow mine.

B, Photomicrograph of chalcopyrite, *cp*, partly weathered to limonite, *li*, enclosing unaltered enargite, *e*.

C, *D*, Photomicrographs of ore minerals in jasperoid from the Aubrey mine. *C*, Tennantite, *t*, and luzonite, *lz*, enclosed in supergene chalcocite, *c*, which is etched. *D*, Chalcocite, etched, *c*, replacing tennantite, *t*.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period, when the streams had a very low gradient. During this period of sluggish erosion, chemical weathering became increasingly active through the oxidizing, hydrating, and solvent effects of ground water. The carbonate minerals of the calcareous rocks were dissolved, and a deep mantle of soft residual clay was formed. The minerals of the noncalcareous rocks were oxidized and hydrated, but these rocks yielded no soft residual clays, because the effects of solution were slight.

The residual clays of the Highland Rim, in the areas underlain by calcareous rocks, were removed more rapidly during Coosa erosion than the weathered noncalcareous rocks, and the surface was selectively lowered in the areas containing the clays. Degradation was arrested as the stream gradients in these areas reached the new base level, which was only 200 feet below the level of the Highland Rim. Aggradation began in the lower parts of the valleys and advanced upstream, maintained by continued erosion of the residual clays underlying the steeper headwater slopes. The process resulted in the deposition of the alluvial deposits of sandy clay containing smoothly worn boulders and pebbles, whose remnants are described on pages 23-24, and continued until aggradation reached the headwater valleys, checking the removal of slope-washed debris. The debris continued to accumulate as a mantle of diminishing thickness upslope, forming the deposits of colluvium described on pages 24-25, which reduced the surface gradient and checked vigorous erosion. Chemical weathering again became active, and the dissected mantle of residual clay was thickened by solution of the underlying calcareous rocks.

Since the development of the Coosa terrace, renewed erosion has removed all except remnants of the alluvial valley deposits, and the stream courses are now about 100 feet below the Coosa terrace level. A fairly continuous blanket of the colluvium remains, however, on the headwater slopes underlain by calcareous rocks and their mantle of residuum.

SECONDARY MINERAL DEPOSITS

CHARACTERISTIC OCCURRENCE

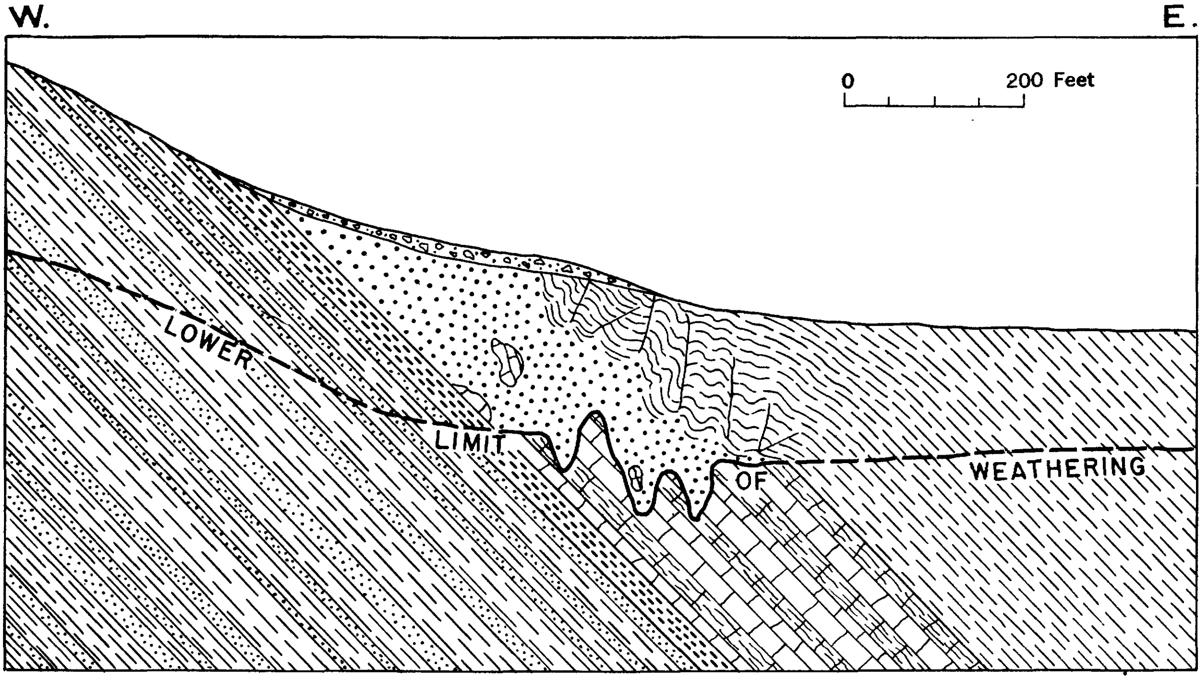
The secondary mineral deposits of economic importance contain barite identical with that exposed in dolomite of the Rome formation, and they also contain manganese oxide minerals, limonite, and goethite, which do not occur in any of the fresh rocks. These minerals are enclosed, both separately and together in various proportions, in the clays residual from the calcareous rocks of the Rome formation and from the rocks of the Shady formation. Many of the secondary deposits are in and adjacent to well-defined but deeply weathered fault zones, but the bedrock adjacent to the other deposits is so obscured by weathering, and so largely concealed by colluvial overburden, that structural details cannot be determined. Some of the faults that are best exposed are described in the section on representative mines.

Natural exposures of the ore-bearing residuum are not common, and never have been common during the mining history of the district, for the residuum is covered in most places by colluvium. Surface showings of the ores have been found most commonly near the upslope limit of the colluvium, where the surficial deposit is thin. They consist of float ore weathered out of the colluvium, and of ore-bearing residuum exposed by the erosion of the colluvium. The characteristic occurrence of the secondary mineral deposits is illustrated in cross section by figure 5. The deposits of barite and manganese and most of the deposits of brown iron occur in the residuum of carbonate rocks and associated highly calcareous metashale of the Rome formation. The deposits of ocher and umber—in places containing minor amounts of the other ore minerals—occur in the residuum of the Shady formation. The colluvial cover makes the exploration of such deposits difficult, as the diagram indicates, and hence few of the deposits have actually been mined out.

BARITE DEPOSITS

Barite occurs unevenly in the residual clays, and is commonly accompanied by angular boulders of jasperiod. The barite is identical with that in the dolomite, consisting of white aggregates of curved crystals; but in some of it, in the shallower parts of the clay, the cleavage is emphasized by weathering, and the barite has a granular or friable texture. The smallest particles of barite are less than 1 millimeter in diameter and the largest mass observed is 4 feet across. (See pl. 14*D*). Most of the residual masses, however, are from one-half inch to 6 inches across. They are highly irregular in shape, and the surfaces are smoothly concave and convex like the contacts between barite and dolomite.

The barite encloses very small amounts of pyrite, commonly near the exterior of the masses. Much of the pyrite has been partly or entirely weathered to limonite. Other sulfides present in minute amounts include tennantite partly weathered to chalcocite, chalcopyrite partly weathered to malachite, galena partly weathered to cerussite, and sphalerite. The residual barite in the clays is distributed very unevenly, but probably not so unevenly as in the original dolomite, for the slumping of the clay, caused by continued solution of the underlying bedrock, has tended to disperse the barite originally confined to veins. Barite constitutes more than 50 percent of the total weight of some small bodies of the residuum, but the average proportion of recoverable barite in



EXPLANATION

BELOW THE ZONE OF WEATHERING		IN THE ZONE OF WEATHERING
Does not occur	Colluvium	Deep-red to yellow sandy clay; boulders of jasperoid and quartzite and fragments of the residual areas unevenly present
	Formed since Tertiary time	
Does not occur	Residuum	Dark- to light-brown clay and masses of jasperoid; quartzite boulders common in upper part. In places contains barite, manganese, and brown iron ore separately or in various proportions
	Formed since Cretaceous time	
Bluish- to greenish-gray; variably calcareous. Contains a few of the deposits of primary minerals other than hematite	Metashale of the Rome formation	Strongly leached; colors white, yellow, and brown. Mostly remains in place, but solution of underlying dolomite causes lower beds to slump and disintegrate, forming much of the residuum.
Variably micaceous; partly silicified in places. Contains most of the deposits of primary minerals other than hematite	Dolomite of the Rome formation	Dolomite destroyed by solution; less-soluble constituents remain in the residuum
Interbedded siliceous, specular hematite, and partly silicified dolomite	Shady formation	Strongly leached to ocherous and umberous bedded clays containing residual hematite
Interbedded quartzite and metashale, each dark gray to black	Weisner formation	Mildly leached; colors white, yellow, and light gray

Lower Cambrian — CAMBRIAN

FIGURE 5.—Diagrammatic cross section showing typical geologic occurrence of most of Cartersville mineral deposits.

large deposits ranges from 11.8 to 17.5 per cent.

Prismatic, singly-terminated crystals of barite occur in the zone of weathering at some of the barite deposits. They occur individually and in clusters, attached to quartzite, jasperoid, and limonite. These chystals differ from those deposited with jasperoid (see pp. 47, 50), which are not terminated and may be found in fresh as well as in weathered rock. The terminated crystals are nowhere abundant enough to be of economic importance. As they occur only in a weathered environment, they are undoubtedly of supergene origin, as already pointed out,[9] and probably account for the minor amounts of BaO (0.40 and 0.15 percent) which Hull[10] has reported in Weisner quartzite forming the footwall of the Bertha deposit. Barite crystals of this type are partly replaced by manganese oxide at the Georgia Peruvian mine but have been deposited on manganese oxide at the Green mine.

MANGANESE DEPOSITS

Black manganese oxide, commonly intermixed with brown iron oxide, occurs in finely disseminated and concretionary forms in the clays residual from carbonate rocks and in weathered calcareous metashale. Most of the bodies of manganese-bearing clay have highly irregular outlines, but some of them have a sharply defined lenticular form and are called "streaks" by the miners. Some of the "streaks" may be found in barren clay, but most of them occur in large, irregular bodies of manganiferous clay containing less manganese than is present in the "streaks."

Many of the concretions, which are locally called dornicks, are concentrically layered. In a single concretion some layers consist of dull, massive manganese oxide of psilomelane type, and others consist of finely prismatic crystals with bright metallic luster, oriented at right angles to the layers. Aggregates of tiny tabular crystals of manganese oxide encrust a few of the concretions, and occur in veinlike aggregates in some of the deeply weathered jasperoid. Qualitative chemical determinations and X-ray examinations of typical specimens, made in the laboratory of the Geological Survey,[11] show that the manganese oxide in both the prismatic and the tabular crystals is pyrolusite, and that much if not most of the massive manganese is probably the potash-bearing mineral cryptomelane,[12] containing a little barium.

A rare massive variety found at and very near the surface has a bluish cast and contains a small amount of cobalt. Pierce[13] mapped and sampled the Gemes deposit, which contains from 0.5 to 1.3 percent of cobalt, and collected an ore sample containing 1.6 percent of cobalt from the Ward or north Vaughn deposit (No. 31). The bluish oxide of both deposits was found to be a mixture of hollandite and lithiophorite.

Mineral impurities, other than iron oxide, that occur in the manganese-oxide ores include vein quartz, jasperoid, halloysite, and barite. The vein quartz and jasperoid occur as small fragments enclosed in the manganese, and cannot be removed without prohibitively fine crushing. They are common impurities in all the manganese deposits. Vein quartz, irregularly distributed, is especially abundant in the manganese ore in the Pauper Farm-Collins deposit.

Halloysite and barite are less common impurities. Halloysite, whose presence at the Gemes mine was noted by Watson,[14] occurs in greatest quantity in the western part of the Vaughn mine (No. 31) where it encrusts and fills cavities in much of the ore. It adheres tightly to the manganese, and is only partly removed by log washing. Supergene barite crystals are attached to the walls of spongelike manganese ore at the Green mine, and are enclosed in manganese nodules in a small barite deposit on the west slope of Ponder Mountain. No primary barite has been seen enclosed in massive manganese ore, although manganese oxide encrusts residual primary barite in deposits between Ponder Mountain and Emerson.

Minute amounts of cobalt, nickel, copper, lead, and zinc have been reported in spectrographic analyses of some of the manganese ores made in the laboratory of the Burgess Battery Co.[15] The copper, lead, and zinc are probably derived from the weathering of primary sulfides, for these have been found at a number of the mineral deposits, but there is no basis for inferring the source of the cobalt and nickel.

DEPOSITS OF BROWN IRON ORE

The brown iron ore is mostly massive limonite of dull luster, but it commonly contains sinuous veins and crusts of goethite which forms acicular crystals arranged in radial clusters. The surfaces of these clusters in open spaces are commonly botryoidal; they are black, and have a strong metallic luster.

The matrix of the brown ore is the residuum of calcareous rocks, mostly of the Rome formation but partly of the Weisner. The residuum of the Rome rocks is of two varieties. One of these is brown clay, similar to that in which the barite occurs, containing irregular masses of the brown ore and angular boulders of jasperoid; the brown clay is derived from the weathering of carbonate rocks and very calcareous metashale. The other variety is light-brown to white clay that is sharply bedded and that contains fairly regular layers and lenticular masses of the brown ore; the light-colored clay is

[9] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Am. Inst. Min. Eng. Trans., vol. 30, p. 418, 1901.

[10] Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, p. 25, 1920.

[11] Chemical determinations by Michael Fleischer; X-ray examinations by Joseph Axelrod.

[12] Richmond, W. E., and Fleischer, Michael, Cryptomelane, a new name for the commonest of the "psilomelane" minerals: Am. Mineralogist, vol. 27, pp. 607-610, 1942.

[13] Pierce, W. G., Cobalt-bearing manganese deposits of Alabama, Georgia, and Tennessee: U. S. Geol. Survey Bull. 940, pp. 271-275, 1944.

[14] Watson, T. L., Preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, p. 83, 1908.

[15] Information from G. D. Murray, Burgess Battery Co.

derived from the weathering of moderately calcareous to noncalcareous metashale, which retains its bedding.

The matrix derived from Weisner rocks is similar to that derived from metashale of the Rome formation and similarly contains brown ore in layers and lenses. It occurs, however, in narrow, conformable zones in the normal, more resistant Weisner rocks, which consist of noncalcareous metashale containing thick beds of quartzite and metasiltstone. (See description of the Vineyard Mountain mines pp. 85-86).

Brown ore occurs also in two environments in which it is seldom abundant enough to be of economic importance. One of these is the umberous and ocherous residuum of the bedded specular hematite in the Shady formation, which contains scantily and irregularly distributed limonite. The other is the brecciated quartzite of the Weisner formation whose outcrops define many of the faults shown on the geologic map. The limonite cements the breccia fragments (see p. 27) and has attracted prospecting at many places, but only at the Peachtree deposit has it been found in sufficient abundance to be worth mining.

DEPOSITS OF OCHER AND UMBER

The deposits of ocher and umber consist of finely intermixed limonite and clay, with smaller and variable proportions of fine-grained quartz and muscovite. Flakes and slabs of specular hematite occur irregularly in some deposits, but to recover it requires highly selective mining; and the most extensively worked deposits contain little or none of it. The deposits occur in the weathered, surficial part of the Shady formation, and are thin-bedded, with a conformable relation to the underlying Weisner rocks. (See description of the Roan mine.)

Nodules of psilomelanelike manganese oxide are irregularly distributed in some of the deposits. Finely disseminated manganese oxide also is present in variable quantity, and its proportion determines whether the material is classed as ocher or as umber. Material containing not more than 2 percent of MnO_2, and sufficient ferric hydroxide to impart a bright orange-yellow color, is ocher of possible economic grade. Material containing as much as 5 percent of MnO_2, and ferric hydroxide in an amount approximating that in the ocher that is mined, is chocolate-brown in color and is umber of possible economic use as iron ore; it has the texture of stiff putty when mined, but becomes hard and brittle when dry.

According to the producers, the crude ocher mined in recent years has contained from 45 to 56 percent of Fe_2O_3. Wilson[16] gives analyses showing a range of 40 to 50 percent of Fe_2O_3 in ocher from recently active mines, and as little as 18.7 percent in material of possible economic grade. He classed all this material as sienna because of its orange-yellow hue, and distinguished "light grayed" and "dark grayed" varieties, the former being the more brilliant. Variations in composition are indicated by differences in the color of adjacent beds and in that of material in different parts of the same bed.

Jasperiod, which occurs in irregular masses, is commonly present where ocher is most abundant, but is rare in material consisting chiefly of umber. Wherever structure can be determined, as at the New Riverside and Howard ocher mines, the jasperiod is most abundant where faults cut the contact between the Weisner and Shady formations. Residual barite also commonly occurs in the weathered fault zones, and both the jasperoid and the barite in places contain fossils characteristic of the Shady formation.

A little ocher occurs in quartzite of the Weisner formation. At the Georgia Peruvian mine, operations were restricted mostly to the weathered part of the Shady formation but were extended into the underlying quartzite of the Weisner formation where ferric hydroxide, obviously derived from the overlying deposit, had been deposited irregularly in tension fissures. Clear terminated crystals of supergene barite are attached to the walls of the fissures.

ORIGIN

PREVIOUS INTERPRETATIONS

It has been recognized by all geologists who have previously examined mines in the district that the principal factor in the origin of the deposits of present economic importance has been weathering. There has been considerable speculation, however, regarding the primary sources of the ore minerals in the secondary deposits.

The eariest definite evidence as to the origin of any of the ores was reported by McCallie[17], who observed iron carbonate at the Sugar Hill mines. He published an analysis of the carbonate and ascribed the origin of the brown ore to its oxidation. Hayes and Eckel[18] believed that the brown ore cementing brecciated quartzite was formed by the oxidation of pyrite and iron carbonate deposited in fault zones by ascending solutions and that the manganese oxide, the ocher, and the brown ore not cementing brecciated quartzite were formed by the

[16] Wilson, Hewitt and others, Iron oxide mineral pigments of the United States: U. S. Bur. Mines Bull. 370, p. 43, 1933.

[17] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, pp. 19, 162-163, 1900.

[18] Hayes, C. W., Manganese ores of the Cartersville district, Georgia: U. S. Geol. Survey Bull. 213, p. 232, 1903. Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Georgia: U. S. Geol. Survey Bull. 213, pp. 239-242, 1903; Occurrence and development of ocher deposits in the Cartersville district, Georgia: U. S. Geol. Survey Bull. 213, p. 429, 1903.

oxidation of dissolved or precipitated carbonates leached from the associated rocks by ground water.

Catlett[19] made a study of the iron carbonate at the Sugar Hill mines and found that it enclosed pyrite. He concluded that the carbonate was formed by reaction between dolomite and supergene sulfate solutions derived from pyrite and that the carbonate was subsequently weathered to form the brown ore.

Watson[20] agreed with Hayes in regarding the ocher and the manganese oxide chiefly as products of the oxidation of supergene carbonates derived from the widespread leaching of the associated rocks. He believed, however, that a substantial part of the ferric hydroxide in the ocher deposits was derived directly from pyrite, which he found to be intimately associated with the deposits.

Hayes and Phalen[21] described the occurrence of residual barite long before it was mined on a large scale. They considered it likely that barium carbonate had been introduced by thermal springs and had reacted with gypsum to form the barium sulfate.

LaForge[22] believed that the ore-forming constituents of the manganese, iron (presumably brown ore), ocher, and barite deposits were all leached from the associated carbonate rocks, and possibly from overlying rocks, by meteoric water and that these constituents were deposited during successive periods of peneplanation in the weathered material residual from the rocks. He cited the close association of these deposits as evidence of similar origin, but gave no examples of peneplain deposits.

Hull[23] regarded the deposits of manganese oxide, brown iron ore, and ocher as erosionally concentrated from syngenetic minerals in the associated rocks and was the first to point out the occurrence of the white massive barite in primary veins in dolomite. He described as typical a downslope succession of residual brown iron and ocher, manganese ore, and barite where the direction of slope and dip of the underlying rocks is the same. This succession was interpreted by him to indicate a stratigraphic succession in the occurrence of the source minerals. As this succession is also the order of increasing specific gravity, Hull believed that the zoning was effected by selective concentration during weathering, apparently overlooking the fact that the relation between slope and dip would give the same zoning without selective concentration. A practical objection to Hull's theory of gravity concentration is afforded by the erosion of cassiterite deposits in North Carolina, under climatic conditions similar to those of the Cartersville district. The lighter materials residual from the weathering of these deposits are transported downslope more rapidly than the heavy cassiterite.

Crickmay[24] ascribes the origin of the baritic clays to the weathering of quartzite of the Weisner formation and dolomite of the Shady formation containing fracture-filling and replacement bodies of barite, the origin of the manganiferous clays to the weathering of transition beds between quartzite of the Weisner formation and dolomite of the Shady formation, and the origin of the ocher deposits to the deposition of iron from groundwater, plus the oxidation of pyrite in place, in quartzite of the Weisner formation.

Some preliminary conclusions regarding the origin of the mineral deposits have been given by the writer[25]. These accord in general with the conclusions given in the present report, but some details have been revised and clarified by further work.

PRESENT INTERPRETATION

Barite is the only one of the primary ore minerals previously described that occurs in economically important amount in the secondary mineral deposits. The white barite in the residual clays is identical with that in the barite veins rarely exposed in dolomite and contains the same primary sulfides, commonly altered by weathering, in small amounts. The residual barite is most abundant in the residual clays near known faults and has evidently been freed from dolomite by the leaching away of the carbonate rock. Barite-bearing residuum is known to exceed 100 feet in depth at some of the mines, and the deep leaching of the dolomite is believed to have occurred during the periods of active chemical weathering and sluggish erosion following Highland Rim and Coosa planation.

The specular hematite, which occurs with ocher and umber in the weathered outcrops of the Shady rocks, is relatively abundant in places and has been mined in the past. Where the sporadic masses of hematite are exposed in place, they grade into the enclosing ocher and umber and are similarly thin-

[19] Catlett, Charles, Discussion, in Am. Inst. Min. Eng. Bi-monthly Bull. 24, pp. 1179-1183, 1908.

[20] Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, pp. 57-66, 1906; Preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, pp. 53, 149-157, 1908.

[21] Hayes, C. W. and Phalen, W. C., A commercial deposit of barite near Cartersville, Georgia, in Contributions to economic geology, 1907: U. S. Geol. Survey, Bull. 340, pp. 458-462, 1908.

[22] LaForge, Laurence, The Cartersville district, in Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 63-64, 1919.

[23] Hull, J. P. D., Manganese ore deposits, in Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 70-72, 1919; Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, pp. 12-17, 31-34, 1920.

[24] Crickmay, G. W., The ore deposits of the Cartersville district, Georgia: 16th Internat. Geol. Cong. Guidebook No. 2, pp. 126-139, 1932; Discussion, in Econ. Geology, Vol. 30, pp. 563-564, 1935.

[25] Kesler, T. L., Sienna ("ocher") deposits of the Cartersville district, Georgia: Econ. Geology, vol. 34, pp. 324-341, 1939; Structure and ore deposition at Cartersville, Georgia: Am. Inst. Min. Met. Eng. Tech. Pub. 1226, 18 pp., 1940.

bedded. The relation is typically one of hydration of the hematite during weathering. Underground work at the Roan mine is said to have reached a depth of 200 feet. The hematite on the dumps is much less hydrated than that exposed near the surface, indicating that the proportions of ocher and umber diminish with depth. The products of hydration, which also include a little unevenly disseminated limonite, are undoubtedly absent below the limit to which ground water has permeated. The formation below that depth is believd to consist entirely of interbedded specular hematite, which is unevenly siliceous, and dolomite, whose residuum is interbedded with ocher and umber at the surface.

The unusual abundance, in weathered fault zones as that at the New Riverside mine, of ocher and jasperoid commonly accompanied by barite suggests that primary pyrite may locally have been a partial source of the ferric hydroxide in the ocher, for pyrite is a common associate of both jasperoid and barite. The suggestion is given some support in a report by Watson[26], who examined many of the ocher mines during the period in which most of them were in operation and found in most of them siliceous rock containing pyrite partly weathered to ferric hydroxide. He called the siliceous rock quartzite, but his descriptions of the megascopic and microscopic character of the rock accord with the appearance and texture of jasperoid.

The common occurrence of large amounts of fine-grained pyrite in the lower parts of brown-ore mines (see p. 45) is the only dependable criterion of the origin of limonite (not in the residuum of hematite of the Shady formation) that the writer has seen. The sulfide is so abundant in some of the fresher waste as to show clearly why the mines were abandoned. Polished sections show that the limonite replaces the pyrite, the alteration invariably propressing from the margin toward the core of masses of pyrite or of jasperoid containing pyrite. The reported occurrence of iron carbonate as a source of limonite at the Sugar Hill mines (p. 54) could not be verified in the present work, but is given full credence. As the writer has found no siderite, he can make no estimate of its importance, relative to that of pyrite, as a source of the brown ores.

As pyrite occurs throughout the district, and is particularly abundant at some of the brown-ore mines, it would seem that its weathering in the presence of carbonate rocks would form calcium sulfate in appreciable amounts. Calcium sulfate has been found, however, only at one locality, where it is in the form of gypsum. The gypsum occurs in very small amounts in partly weathered, pyritic jasperoid in brown-ore mine No. 1 shown on the geologic map. The extreme scarcity of gypsum indicates that sulfate compounds formed during weathering are removed from the part of the zone of weathering that is above the level of ground water and may in part account for the origin of the supergene barite described on pages 52-53.

The conditions under which barite is soluble in ground water are unknown. The mineral is almost insoluble in pure water, but Clarke[27] has summarized published reports which show that some mine and spring waters contain relatively large amounts of barium sulfate. Barite is precipitated by sulfate solutions and therefore would be insoluble in ground water associated with the oxidation of pyrite. The supergene crystals have terminal faces and are attached to the walls of openings; they occur in the upper part of the zone of weathering, which is characterized by a lack of sulfates and is intermittently penetrated by downward-seeping meteoric water.

The solution of barite, which necessarily preceded the deposition of the supergene crystals, must have occurred in the sulfate-free environment. Deposition may have occurred locally wherever the solution came in contact with rock containing pyrite not completely oxidized. That solution of barite does occur under the influence of weathering is illustrated in plate 14*E*, *F*. The barite shown is of the tabular variety described on pages 47, 50, and the specimens were collected from the residuum of dolomite of the Rome formation in the wall of the Kelly mine. The crystals shown in plate 14*E* are coated with white, porcelainlike, supergene quartz. Most of the barite has been weathered out of the specimen shown in plate 14*F*, leaving the delicate coatings as molds of the crystals.

No primary source mineral of the manganese oxide minerals has been found. The oxides are clearly secondary, for they replace jasperoid at the Blue Ridge mine, metashale at the Boneyard and Alexander mines, and supergene barite at the Georgia Peruvian mine. The deposits occur only in the residuum of carbonate rocks, and they obviously reflect some mode of concentration, for they are separated by large areas of residuum essentially barren of manganese. Most of the ore-bearing residuum is that of the calcareous rocks of the Rome formation but is not restricted to any stratigraphic part of the series. The deposits occur at all altitudes between 700 and 1200 feet and show no relation to either present or previous surface drainage. The drainage of ground water is not related to surface drainage, because, owing to the great thickness of the residuum, there is unrestricted movement of ground water to depths known to be in some places more than 200 feet.

26 Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, p. 62, 1906.

27 Carke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, pp. 590-591, 1924.

The analyses given in table 1 show that the manganese content of carbonate rocks of the Rome formation is negligible and that it is not appreciably greater in and near the manganese mines than at a distance of several miles from any known deposit. The carbonate rocks, therefore, cannot be the source of the manganese oxides or of the iron oxide so commonly associated with them.

Stose[28] has reviewed the findings of geologists who have studied the manganese deposits of Tennessee and Virginia, and concludes that the manganese is derived, through weathering, from the basal beds of the Shady dolomite. These basal beds probably correspond to the Shady formation of the Cartersville district, as defined on pages 10-12. In this district, however, the residuum of the Shady rocks contains only a few small nodules of manganese oxide, irregularly distributed and of no economic importance. Furthermore, the manganese deposits are not associated consistently with the Shady formation, as may be seen on the geologic map; they occur locally in the residuum of relatively small parts of the carbonate rocks and calcareous metashale of the Rome formation.

The most important facts bearing on the origin of the manganese oxide ores are the restricted localization of the ores, and the occurrence of several of the deposits adjacent to clearly defined faults. (See the geologic map and descriptions of mines.) In both respects the manganese deposits are closely related to the deposits of barite and brown iron ore. Manganese ores and residual barite ores occur together in six deposits between Ponder Mountain and Etowah River; and even in the northern part of the district, where barite had not previously been reported, a manganese deposit (No. 52) 0.3 miles southwest of the Black Bank brown-ore mine was found to contain tabular crystals of barite enclosed in pyritic jasperoid. Similar pyritic jasperoid from the Aubrey manganese mine contains tennantite and luzonite.

It seems possible if not probable that the manganese oxides have been formed by the weathering of a primary manganese mineral, possibly manganese sulfide or carbonate, that was deposited unevenly but contemporaneously with the primary minerals from which the other ores have been derived. This conclusion is based on the close association in places of the manganese oxide minerals with residual primary sulfides and barite of undoubted hydrothermal origin and on the similar structural relationships that characterize the best-exposed deposits of all the ore minerals, including those of manganese. The manganese deposits, like the brown-ore deposits, are believed to be essentially gossans, containing the manganese that has not been carried away by ground water during chemical weathering.

[28] Stose, G. W., Source beds of manganese ore in the Appalachian Valley: Econ. Geology, vol. 37, pp. 163-172, 1942.

PRODUCTION METHODS

The methods used in mining and concentrating the Cartersville ores are quite different from those used in hard-rock mining, with which most geologists and engineers are more familiar. They are briefly outlined in the following section merely to show the basic procedure for which provision must be made, under conditions prevailing to 1944, in planning a new operation. Profitable application of this procedure depends on the amount, grade, and accessibility of ore-bearing material in a deposit. The term bank ore is used herein to designate residual clay and deeply weathered metashale whose average content of ore minerals is sufficient to permit mining and concentration at a profit.

BROWN IRON AND UMBER

Brown iron ore was mostly mined by hand from 1840 to about 1905, and afterward by power shovel. All of it has been mined from open-cuts. The original outcrops of many of the brown-ore bodies were massive, and considerable blasting is said to have been done in early mining. In general, however, the massive structure of the ore has been found to decrease with depth, and little blasting is now necessary. In some deposits, the bank ore consists of angular masses of limonite, of widely different sizes, enclosed in residual clay. In other deposits, it consists of lenticular bodies of limonite enclosed in weathered thin-bedded metashale. The clay and metashale greatly exceed the ore in volume. Residual boulders of jasperiod, some of which are as much as 10 feet thick, are less easily removed with shovels than the larger masses of ore, which are commonly fissured and hence become partly broken up in the process of mining.

In recent years, umber has been shipped as a "soft" iron ore from the Bertha, Green, and Cherokee mines. The aggregate output from these mines was about 20,000 tons and contained 42 to 50 percent Fe and 2 to 8 percent Mn. An unknown amount of umber containing a higher proportion of manganese has been shipped from the Dobbins mine. The umber was trucked directly from the mines to railroad cars and was sintered by the purchaser to form a usable iron ore.

Beneficiation of the brown ore involves only the removal of clay and sand and as much as possible of the fragmental jasperoid, vein quartz, and metashale. The bank ore is unloaded on a grizzly whose bars are 2.5 to 6 inches apart. The larger masses of rock are thrown off by hand, and the larger masses of ore are sledged or crushed mechanically. The clay and smaller masses of ore and rock pass through the grizzly to a log washer of single-log or double-log type, in which most of the clay is washed out and sluiced to the mud pond. The log-washer concentrate is discharged to a revolving or vibrating screen, where water jets remove additional clay, sand, and small particles of ore. The ore and rock left on the screen are discharged to a picking belt, from which the angular fragments or jasperoid and tabular fragments of metashale are removed by hand. The picking belt discharges the concentrate into a loading bin.

Brown-ore concentrates produced in recent years have contained from 43 to 56 percent Fe, from 0.5 to 1.8 percent Mn, from 0.20 to 0.49 percent P, and from 6 to 12 percent insoluble matter. Profitable operation under average conditions requires a yield of 1 ton of concentrates from approximately 3 tons of bank ore.

BARITE AND MANGANESE

MINING

The mining and basic treatment of the barite and manganese bank ores, in general, have been similar up to 1944. Although considerable manganese has been produced by underground mining, particularly before the first World War, by far the greater part of the output of manganese and all of that of barite have come from open-cut operations.

Open-cut mining is now done entirely with power shovels. The walls of the cuts are stable during dry weather, even where mining reaches depths of 50 to 100 feet, but they cave readily during the winter and early spring, diluting the ore and impeding operations. Pinnacles and residual boulders of dolomite have been uncovered in some of the deeper mines. These not only obstruct operations, but, in most instances, indicate that mining is nearing the level of ground water or the lower limit of minable clay, or both.

Hydraulic mining has been attempted in the Paga No. 1 and Winterbottom barite mines and in the Aubrey-Stephenson and Bufford manganese mines. The ore-bearing clay was washed to a sump and pumped to the concentrating plants. These operations encountered difficulties of three types: (1) large residual boulders of jasperoid accumulated on the sump screens more rapidly than they could conveniently be removed; (2) selective mining was practically impossible owing to the "mudding" of the clays and the rapid rate of excavation; and (3) the natural tendency of the walls to cave during wet weather was emphasized by the action of the giants, so that dilution of the bank ore increased as depth increased. Because of these difficulties hydraulic methods are no longer used in mining. It is probable, however, that they afford the most economical means of removing large bodies of clay, and that they can advantageously be used in stripping.

About 12 percent of barite is regarded by the operators as the minimum grade of bank ore to be log-washed and jigged. Records of production, which are given in the description of barite mines, indicate that in the larger individual deposits the average proportion of recoverable barite ranges from 11.8 to 17.5 percent. In the manganese deposits there is such a wide range in the proportion of both nodular and finely disseminated manganese and iron oxides that each deposit must be appraised separately according to the grade of the concentrate that can be made.

Factors that, taken together, are as important as the grade of the bank ore include topography, water supply, behavior of the clay in the log washer, the amount of barren clay that must be stripped, and the proportion of ore minerals lost in the process of concentration.

CONCENTRATION

The methods employed to 1944 in the concentration of barite and manganese ores, and the general grade of the products, are merely outlined here. Detailed descriptions of the basic methods and equipment now in use have been given by Crane,[29] and Hubbell,[30] and other possible methods and equipment are described in papers listed in the bibliography.

Barite and manganese bank ores are log-washed, and the log-washer concentrates are sized for Harz jigs. The size of the jig feed differs somewhat in different operations. In general, the coarser barite jig feed ranges from 1 inch to ½ inch in size and the finer feed from ½ inch to 1/16 inch; the coarser manganese feed ranges from 1¼ inch to ⅜ inch, and the finer feed from ⅜ inch to 1/16 inch. Masses of barite that are too large for the jigs are removed from a picking belt, and are shipped as "lump ore." Oversize manganese is in part shipped as "dornick ore" and in part crushed to the sizes required for jig feed.

Screened barite ore of less than about 1/16 inch particle size is concentrated in sand jigs of Harz type, or on tables. Manganese ore of similar size is concentrated only in sand jigs; the only effort to use concentrating tables was made by the Manganese Corporation of America, at Aubrey, in 1930–31. (See description of the Aubrey-Stephenson and Bufford mines.)

In July 1944, there were in the district six active

[29] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 260-284, 1919.

[30] Hubbell, A. H., New Riverside—producer of barytes in Georgia: Eng. Min. Jour., vol. 143, No. 10, pp. 62-65, 1942.

barite-concentrating plants operated, respectively, by the Paga Mining Co., the New Riverside Ochre Co., the Barytes Mining Co., the Barium Reduction Corp., T. E. Johnsey, and George Shropshire. Special equipment, in addition to the usual log washer and jigs, included tables for the concentration of fines in the plants of the Paga Mining Co. and the New Riverside Ochre Co., and magnetic separators used to reduce the iron content of some of the concentrates in the plants of the New Riverside Ochre Co. and the Barytes Mining Co. A froth-flotation plant, designed to recover barite from the finer products of the Paga Mining Co.'s plant, was being installed by Thompson-Weinman & Co.

There were only two manganese-concentrating plants in operation in July 1944. One of these was being operated by Neel and Neel at Aubrey, and the other by the White Mining Co. at the Pauper Farm mine.

Concentrates produced by the methods thus briefly outlined differ in grade according to the quality of the bank ore from which they are derived. Most of the barite concentrate, which is used in the manufacture of lithopone and barium chemicals, contains from 94 to 96 percent $BaSO_4$, not more than 1.5 percent Fe, not more than 2.5 per cent SiO_2; concentrates used in the manufacture of glass contain from 96 to 99 percent $BaSO_4$, and less than 0.28 percent Fe; and concentrates that are ground for use in high-gravity muds contain 92 to 94 percent $BaSO_4$, and from 2.5 to 5 percent Fe. The grade of manganese concentrates varies much more widely, owing to the wide range in quality of bank ore and to fluctuating market conditions. Concentrates that have been shipped in recent years have contained from 16 to 50 percent Mn, from 2 to 30 percent Fe, from 0.11 to (exceptionally) 0.40 percent P, and from 4.5 to 26.5 percent insoluble material, which consists mainly of clay and quartz.

TAILINGS DEPOSITS

No records have been kept to show proportionate losses of barite and manganese in concentrating the bank ores, but a few data are available concerning the grade of some of the large accumulations of tailings, which have attracted some interest as a possible ore reserve. The most complete data pertain to the manganese jig-tailings deposits. These were measured and sampled by the writer in March 1943, and his samples were screened and analyzed in the laboratory of the Embree Iron Co., agent for the Metals Reserve Co. The weight of these tailings is remarkably uniform, and averages 109 lbs. per cubic foot. The total amount is about 60,000 tons. The results of this work are summarized in table 3. The table shows that the tailings are of lower grade than is commonly supposed, and that the amount of iron is consistently greater than that of manganese. The metallic oxides in these jig tailings are for the most part firmly bonded to particles of jasperoid and vein quartz and can be freed only by crushing to very fine sizes.

The total amount of manganese log-washer tailings is probably between 1,000,000 and 2,000,000 tons. Very little of this material is coarser than 10-mesh, and the greater part is clay and silt. A composite sample taken by Bureau of Mines engineers from a deposit of about 100,000 tons at the Dobbins mine contained 2.4 percent Mn and 20.5 percent Fe.[31] Six other published analyses of log-washer tailings[32] show a range of 2.49 to 20.39 percent Mn, and 5.37 to 18.44 percent Fe. Owing to great differences in quality and the extreme fineness of the manganese oxide, there has been no attempt to beneficiate the manganese log-washer tailings.

TABLE 3.—*Amount and grade of manganese jig tailings in the Cartersville district in March 1943*[1]

Property	Amount (long tons)	Number of samples	Particle size (percent)		Average contents (percent)		
			−12 mesh	+12 mesh	Mn	Fe	Insoluble
Aubrey:							
Average tailings[2] (−⅝″, mostly −¼″)	39,825	11	57.9		5.64	7.84	74.10
				42.1	7.74	10.52	65.53
Rejigged tailings	1,403	1	76.0		5.22	7.90	75.00
				24.0	8.26	10.16	65.60
Appalachian	11,694	4	62.7		5.61	12.54	65.95
				37.3	6.87	15.17	59.60
Dobbins	2,934	2	63.7		13.00	21.77	37.40
				36.3	11.57	21.66	40.55
Blue Ridge	137	1	32.6		6.52	19.15	53.90
				67.4	5.22	19.04	57.40
Pauper Farm	1,032	1	75.4		6.00	11.55	68.00
				24.6	6.09	9.95	72.00

[1]Screening and analyses by the Embree Iron Co., as agent for the Metals Reserve Co.

[2]Values given are weighted averages.

In the barite tailings, on the other hand, it is the finer material that has attracted the most interest. The finer waste consists mainly of log-washer tailings, but some deposits contain a large proportion of fine jig tailings and tailings from concentrating tables. Very little of the material is coarser than 10-mesh, and most of it is minus-35-mesh. The results of screening tests of samples from a large and representative deposit show that about one-third of the material is plus-325-mesh, and two-thirds minus-325-mesh.

The total amount of the finer tailings cannot be estimated closely, as some deposits have been covered with coarser tailings and others are partly eroded. It is probably at least 3,500,000 tons, and possibly as much as 5,000,000 tons. There has been very little sampling of the finer tailings to deter-

[31] Johnston, T. L., Fine, M. M., and Shelton, S. M., Concentration of manganese-bearing ore from the Dobbins mine of Cartersville, Ga.: U. S. Bur. Mines Rept. Inv. 3608, p. 4, 1942.

[32] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., pp. 87, 102, 108, 113, 124, 139.

mine their barite content. Samples from drill holes in two deposits, which may not be identified, contained from 5.1 to 12.2 percent barite, and the richer parts of some deposits, near the point of inflow, are said to contain 20 percent or more.

OCHER

Most of the ocher has been mined from underground workings, although power shovels have been used locally to strip some of the larger deposits. The deposits occur in the Shady formation, in the zone of weathering, and are evenly bedded parallel to the uppermost quartzite of the Weisner formation. The bedding is regular, except where faults cut the deposits, but in the fault zones it is contorted and interrupted by irregular masses of jasperoid. The underground workings have been driven along the ocherous beds near and above the contact; the workings in the weathered fault zones have followed, in sinuous plan, the soft bodies of ocher between the jasperoid masses.

Some ocher has been deposited by ground water in joints and tension fissures in the quartzite underlying the deposits, and the large open-cut at the Georgia Peruvian mine was made in removing the quartzite in order to recover such transported ocher. Many people have an erroneous impression that this open cut illustrates the prevailing mode of occurrence of the ocher, and the customary method of mining it in the Cartersville district, whereas in fact it is exceptional in both respects.

The only refining plant in the district is operated by the New Riverside Ochre Co. The raw ocher is log-washed to remove rock and coarse sand. The over-flow from the washer contains the ocher and fine sand. The sand is removed with a Dorr rake, and the slime is dried in revolving steam drums. The ocher is scraped mechanically from the drums, then pulverized and bagged. The recovery of refined ocher from raw ocher averages about 50 percent by weight, including the loss of free moisture. All the refined ocher contains at least 50 percent of Fe_2O_3, and most of it contains 55 to 60 percent. Specifications require that 99 percent of it shall be minus-325-mesh.

SPECULAR HEMATITE

No hematite ore has been produced since the 1890's except for a trial shipment of two cars from the Bartow Mountain mine in 1941. The hematite occurs in the same stratigraphic position as the ocher, and has been mined in the same way, partly from open-cuts and partly from underground workings. As the hematite beds overlie the rocks of the Weisner formation, the mine workings are oriented parallel to the contact. The presence of the hematite is indicated in many places by abundant float, as the beds are highly weathered and do not crop out. Mining was obviously guided by outcrops of the uppermost quartzite of the Weisner formation.

In comparison with modern methods of beneficiation, the handling of the ore that was shipped was a rather wasteful process. The ore was hand-cobbed to eliminate material containing too much quartz. The amount of silica allowed in the shipped ore is unknown, but the abundance of highly quartzose ore in the dumps at the Roan mine indicates that between one-third and one-half of the ore mined was not of acceptable grade.

PRINCIPAL MINES

PRELIMINARY STATEMENT

There are about 330 mines and prospects in the Cartersville district. Many of them were opened between 50 and 100 years ago, and nearly all have been mined intermittently, periods of operation alternating with longer periods of abandonment. Most of the mining has been done from open-cuts, whose aggregate area in 1944, by the writer's estimate, is about 240 acres. The barite cuts have the largest area, totaling 120 acres. The total for the brown-ore mines is 70 acres, that for the manganese open-cut mines is 45 acres, and that for the open cuts made in mining ocher and specular hematite only about 5 acres.

All the mines and prospects have been examined, and their locations and geologic settings are shown in plate 1. The walls of most of the openings have slumped, and the full extent of the deposits is not apparent owing to the overburden of colluvium.

Records are wholly lacking with regard to most of the mines, and complete with regard to only a few. The records that have been kept relate to output from land under a given ownership, and thus the individual output of very few of the mines can be segregated.

TABULAR SUMMARY

Because of the lack of detailed information, it is impossible to give a useful description of each mine and prospect. The essential data that are available are summarized in table 4. The data are derived from observation and inquiry, and from published and unpublished sources, most of which are cited elsewhere in this report but are too numerous to be cited in the table. Only mines that have been appreciably productive are listed. Many small prospects are omitted, but omission does not necessarily indicate unfavorable outlook.

In the foregoing sections of the report, an attempt has been made to provide an understanding of the origin and geologic setting of the mineral deposits. As all are residual deposits except those of specular

TABLE 4.—*Mines of the Cartersville district that have been appreciably productive*
Data as of 1944

No.	Name	Land lots	District	Type of mining	Maximum depth (feet)	Number of principal open-cuts	Approximate area of principal open-cuts (sq. ft.)	Earliest and latest dates of operation	Total production (long tons)[1]
				Barite					
1	Big Tom	895	4	Open-cut	50	1	100,000	1880–1919	Large
2	Paga No. 2	838, 890, 891, 892	4	do.	35±	3	400,000	1916–41	130,000±
3	Paga No. 1	819, 820, 837, 838	4	do.	150	2	1,350,000	1916–44	635,000±
4	Georgia Minerals	835, 894	4	do.	40	4	35,000	1940–41	6,900
5	Apex	834	4	do.	25	1	7,500	1938	Small.
6	DuPont	762, 823, 834	4	do.	75	2	240,000	1917–44	Large.
7	Iron Hill	786	21	do.	20	3	8,500	1880–1937	300+
8	None	688, 753	4	do.	20	1	10,000	1938–40	1,500±
9	Section House	751, 752	4	do.	90	1	140,000	1917–44	110,000±
10	Nulsen	750	4	do.	120	1	200,000	1905–22?	Large.
11	Georgia Peruvian	764	4	do.	30	2	35,000	1915–41	Moderate.
12	Winterbottom	748	4	do.	80	1	230,000	1924–44	Not disclosed.
13	Slabhouse	677, 691, 692	4	do.	50	1	100,000	1917–44	Large.
14	Abramson	690	4	do.	30	1	8,000	1920's	Small.
15	Larey	678	4	do.	30	2	20,500	?–1941	Moderate.
16	None	604, 605	4	do.	30	1	18,000	1937–42	Do.
17	Jones	624	4	do.	20	1	15,000	?–1919	Small.
18	None	551, 552	4	do.	40	1	85,000	1944–	Moderate.
19	Krebs	548	4	do.	80	1	200,000	1900–37	100,000±
20	New Riverside	533	4	do.	60	1	125,000	1914–28	Large.
21	Big Bertha	478, 531	4	do.	80	1	575,000	1917–44	205,000+
22	Reservoir Hill	530	4	do.	35	1	30,000	1941–42	24,723
23	Clayton	479	4	do.	50	1	40,000	1917–41	20,000±
24	Tucker Hollow	460, 477	4	do.	80	1	250,000	1916–40	45,000±
25	Bertha	475, 476	4	do.	190	1	70,000	1914–39	68,000+
26	Barium Reduction	461, 462	4	do.	00	1	150,000	1919–44	50,000±
27	Munford	460	4	do.	50	1	50,000	1917–34	Large.
28	Parrott Springs	406, 459, 478	4	do.	50	1	350,000	1916–44	46,000±
29	Norris	405	4	do.	40	2	75,000	?–1944	15,000±
30	Cherokee	406	4	do.	50	1	100,000	1939–42	45,000
31	Big Creek	409	4	do.	20	1	8,000	1915–43	Small.
32	Stiles	464	4	do.	15	1	2,500	1915	Do.
33	Hurricane Hollow	329, 330, 392, 393	4	do.	50	1	30,000	1934–40	30,000±
34	Georgia Barium and Ocher	318, 331	4	do.	25	3	15,000	?–1942	Small.
35	None	261	4	do.	25	2	25,000	1937–41	1,000±
				Manganese and ferruginous manganese					
1	None	905, 906	4	Pit, shaft	30	0		?–1908	Small.
2	None	903	4	Open-cut, tunnel	30	1	7,500	1918–41	350
3	None	827, 830	4	Open-cut, shaft, tunnel	20	3	12,000	1908?–39	750±
4	Abramson	826	4	Shaft, tunnel	30±	0		1892–?	500?
5	Dobbs	688	4	Open-cut, shaft, tunnel	50±	3	7,000	1908?–40	Moderate.
6	None	606, 607	4	Pit, shaft, tunnel	30±	0		?–1937	Small.
7	Rhea	543, 544	4	Pit, shaft	30	0		1908?–18	500±
8	None	542	4	Open-cut, shaft, tunnel	30±	2	15,000	1900?–42	150+
9	None	473	4	Open-cut, tunnel	50±	1	2,000	1908?–18	250±
10	None	472	4	Open-cut, shaft	30±	1	1,000	1908?–18	Small.
11	Knight and Barron	465	4	Open-cut, pit	35±	1	10,000	1900–05?	1,200±
12	Stiles	464	4	Open-cut, shaft	70	1	3,000	1918–38	Small.
13	Hebble	391	4	do.	50	1	7,500	?–1938	3,500±
14	Silva	390, 391	4	do.	20	1	15,000	1859–1943	Moderate.
15	Green	460	4	Tunnel (later open-cut, for umber).	40	1	25,000	?–1908	Small.
16	Norris	405	4	Open-cut	40?	1	15,000	1908?–18	3,500+
17	Howard	317, 332, 333	4	do.	50	1	65,000	1908?–44	2,500±
18	Gemes	313	4	Open-cut, shaft	40	3	18,000	1908?–42	2,500±
19	Zeigler	188, 245	4	Open-cut, tunnel	35?	1	15,000	1908?–19	Moderate.
20	None	174, 175	4	Pit, shaft	40	0		1908?–?	Small.
21	None	43, 102	4	Open-cut	40	2	20,000	1918–?	Moderate.
22	Bishop-Smith	234, 235	5	Open-cut, shaft, pit	?	1	4,000	1908–?	Moderate.
23	Russell	199	5	Open-cut	15	1	3,000	1941–42	1,260
24	Wyvern	200	5	do.	25	1	5,500	1916–17	1,750+
25	Dobbins	271	5	Open-cut, shaft	210	10	275,000	1866–1941	43,000±
26	Appalachian	306	5	do.	120	2	120,000	1908?–43	5,000±
27	Milner-Harris-Simpson	272, 305	5	Shaft, pit	?	0		1908?–44	Moderate.
28	Houck	273	5	do.	42	0		1917?–43	Do.
29	Vaughn	268	5	Open-cut	30	1	12,000	1921–?	Do.
30	Blue Ridge	274, 303	5	Open-cut, pit	75	4	75,000	1898–1943	3,800+
31	Vaughn	266, 267	5	Open-cut, shaft	?	2	9,000	?–1940	1,250+
32	Lowry	201	5	Shaft	25?	0		?–1943	Small.
33	Peeples	202	5	Open-cut, pit	15	1	500	1943	Do.
34	Bufford Mountain	275	5	Open-cut, shaft	60	1	5,000	?–1939	Moderate.
35	Will Lee	276	5	do.	160	2	50,000	?–1944	10,500+
36	Bufford	300, 301	5	Open-cut	105	3	420,000	?–1943	Probably 50,000+
37	Little Red Mountain	313	5	Open-cut, shaft	75?	2	8,000	?–1939	Moderate.
38	Big Spring	109	22	do.	75?	2	15,000	1908?–35?	500+
39	New Chumley	144	22	do.	60	1	2,000	1908?–40	Small.
40	Aubrey	299, 300	5	Open-cut	140	1	180,000	?–1938	
41	Little Aubrey	299	5	do.	75?	1	115,000	?–1931	probably
42	Little Stephenson	314	5	do.	30	1	30,000	?–1931	100,000+
43	Stephenson	314	5	do.	75?	1	105,000	?–1940	
44	Bell	314	5	Open-cut, pit, shaft	75	1	15,000	?–1943	Moderate.
45	Chumley Hill	144, 145	22	Open-cut, shaft	149	2	90,000	1886?–1939	Large.
46	Moccasin	143	22	Open-cut, shaft	90?	2	12,000	1886?–1935?	1,000+
47	Red Mountain	146	22	Pit	15	0		?–1908	300±
48	Allison	147	22	do.	15	0		?–1918	Small.
49	Alexander	148	22	Open-cut	25	1	8,000	?–1935	Moderate.
50	Satterfield	315	5	Shaft tunnel, incline	100	0		1908?–40	Do.
51	Boneyard	180	22	Pit, shaft	50?	0		?–1942	Do.
52	Black Bank	185, 186	22	Open-cut, tunnel, shaft	30?	1	1,000	1900?–35?	Small.
53	Wofford	182	22	Open-cut, shaft	?	1	5,000	1890–1918	Small or moderate.
54	Pauper Farm	215	22	Open-cut, shaft, tunnel	60	2	85,000	1908?–44	Large.
55	Collins	214	22	do.	50?	7	75,000	1908?–44	Large.
56	Hogpen	219	22	Pit, shaft, tunnel	?	0		?	Small or moderate.
57	Baker	250	22	Shaft, pit	?	0		?–1918	Small.
58	None	296	22	Open-cut, shaft	?	1	1,000	1917–35?	Small.
59	Vaughan	319	23	Shaft, pit	70	0		1917–18	Small.

TABLE 4.—*Mines of the Cartersville district that have been appreciably productive*—Continued

No.	Name	Land lots	District	Type of mining	Maximum depth (feet)	Number of principal open-cuts	Approximate area of principal open-cuts (sq. ft.)	Earliest and latest dates of operation	Total production (long tons)[1]
				Brown iron					
1	None	1124	4	Open-cut	20	2	7,000	?-1900	Moderate.
2	Chulafinnee	1050	4	do.	40	1	100,000	1879-1943	25,000+
3	Cemetery Hill	1040	4	do.	50	2	80,000	1876-1908	Large.
4	Sloan	1039	4	do.	20	1	15,000	1870-?	Moderate.
5	Kelly	981	4	do.	35	5	100,000	1900?-43	Moderate or large.
6	Convict	966, 979	4	do.	20	2	100,000	1872-?	Do.
7	Bartow No. 1 (Bartow group)	903, 904, 969, 970	4	do.	100	1	100,000	1862-1939	Large (probably 500,000+)
8	Lyle (Bartow group)	903, 970	4	do.	60	1	70,000	1940-43	87,000 (probably 500,000+)
9	Bartow No. 3 (Bartow group)	901, 902, 971	4	do.	35	1	165,000	1862-1941	Large (probably 500,000+)
10	Bartow No. 2 (Bartow group)	898, 899	4	do.	50	1	75,000	1862-?	Large (probably 500,000+)
11	None	866?	21	do.	15	1	1,000	?	Small.
12	Iron Hill	728, 729	21	do.	130	2	125,000	1861?-1923	300,000±
13	Wheeler	648	21	do.	50	1	100,000	1860's-1916	60,000+
14	None (Vineyard Mountain group)	578, 579	21	do.	30	2	20,000	1861?-1914	Moderate (probably 100,000±)
15	None (Vineyard Mountain group)	578	21	do.	40	1	20,000	1861?-1914	Large (probably 100,000±)
16	None (Vineyard Mountain group)	575	21	do.	60	3	45,000	1861?-1914	Large (probably 100,000±)
17	None (Vineyard Mountain group)	506, 575	21	do.	30	1	17,000	1861?-1914	Moderate or large (probably 100,000±)
18	None	576	21	do.	30	1	25,000	1899	1,000±
19	None	612	4	do.	35	1	35,000	1899	2,000±
20	None	679	4	do.	25	1	20,000	?-1900?	Moderate.
21	Larramore	466, 471	4	do.	15	2	1,000	?-1861	Small.
22	Big	465	4	do.	40	1	15,000	?-1861	Moderate or large.
23	Riverside-Hurricane Hollow	329, 330, 392, 393, 400	4	do.	70	3	225,000	1861?-1920	525,000±
24	Kennedy-Franklin	171, 172	4	Open-cut, pit, shaft	30	3	15,000	1902?-18	Moderate with ferruginous manganese).
25	Felton	96?	4	Open-cut	30	1	70,000	1890-?	Moderate or large.
26	Guyton	200	5	do.	25	1	85,000	1860's-1944	Do.
27	Lowry	201	5	do.	20	1	15,000	1890's	Moderate.
28	Munford	202	5	do.	80	1	50,000	1886?-1907	100,000±
29	Bishop	275	5	do.	30	1	15,000	1890's	Moderate.
30	None	276	5	do.	60	1	150,000	1860's-1905?	Large.
31	Bufford Mountain	301	5	do.	40	1	80,000	1860's-1890	Large.
32	Wildcat Hollow group	312; 108, 109	5; 22	do.	40	7	110,000	1886?-1902	Large.
33	Peachtree	148	22	do.	60	2	12,000	1861?-1880's	Moderate.
34	Conner	181	22	do.	25	1	45,000	1886?-1915	Large.
35	Big Mountain	179, 182	22	do.	80	2	55,000	?-1900	Large.
36	Black Bank	186	22	do.	30	2	10,000	1861?-?	Moderate.
37	Bluff (Sugar Hill group)	257	22	do.	30	2	25,000	1861?-1906	2,500,000±
38	Pine Hill (Sugar Hill group)	257	22	do.	?	1	150,000	1861?-1906	2,500,000±
39	Cripple Creek (Sugar Hill group)	258	22	do.	25	1	20,000	1861?-1906	2,500,000±
40	Sugar Hill-Kinsey (Sugar Hill group)	258	22	do.	75	1	700,000	1861?-1906	2,500,000±
41	None (Sugar Hill group)	283	22	do.	65	1	25,000	1861?-1906	2,500,000±
42	Bennett	296	22	do.	30	1	80,000	1900?-23	Moderate.
43	None	317	22	do.	15	1	4,000	?-1918	200+
				Ocher					
1	Georgia Peruvian	676, 677, 692, 693, 748	4	Shaft, tunnel, open-cut	230	2	35,000	1878-1931	Not available individually. Aggregate production, together with that of smaller workings, is about 340,000 short tons.
2	New Riverside	533	4	do.	50?	1	(2)	1902?-28	
3	American	475, 534	4	Pit	30	0		1902-?	
4	Knight	404	4	Open-cut, tunnel	50	1	75,000	1927-44	
5	Cherokee	406	4	Open-cut, shaft	70	1	35,000	1894-1941	
6	Blue Ridge	390	4	Tunnel, pit	?	0		1899-?	
7	Southern	330, 391	4	Open-cut	25	1	10,000	1942-44	
8	Georgia Barium and Ocher	319	4	Open-cut, tunnel	35	1	10,000	1902?-44	
9	Howard	317	4	do.	25	1	6,000	1941-42	
				Specular hematite					
1	Roan	616, 679, 680, 681	4	Shaft, tunnel, pit	200?	0		?-1878	Possibly 25,000+
2	Red No. 1	300	5	Open-cut	40?	1	75,000	1880's-1890's	Moderate or large.
3	Red No. 2	299, 313, 314	5	do.	100?	2	70,000	1880's-1890's	Possibly 25,000+

[1]Mostly estimates. Large, more than 10,000 tons; moderate, 1,000 to 10,000 tons; small, less than 1,000 tons.
[2]Obliterated by barite mining.

hematite, there is a geologic sameness among those of each type, which makes such an understanding more useful for future development than hearsay regarding past mining.

In the sections that follow the tabular summary, only those mines are described whose geologic details or output, or both, are sufficiently well known to make the descriptions useful to the geologist and mining engineer. The mines described are representative of those throughout the district, and the geologic conditions obtaining at any mine or prospect not described may be inferred from descriptions of those whose geologic setting, as shown in plate 1, is similar. Stratigraphic sections can be measured at only a few of the mines owing to the deep weathering of the calcareous rocks. The best-exposed sections are shown in plate 5.

In the part of Georgia that includes the Cartersville district, the land is divided into districts 9 miles square, and the districts are divided into square lots. All land ownerships and leases are recorded in these terms, and the locations of the mines listed and described in this report are given accordingly, although the land divisions are not shown in plate 1.

In some of the land districts, the lots contain approximately 40 acres each, as in the southern part of the mining area. In other districts the lots contain approximately 160 acres each, as in the northern part of the mining area. There is no map showing these land divisions accurately for the entire Cartersville district, for it is known that some errors were made in the original surveys. The office of the County Commissioners, in the court house at Cartersville, has for sale a map showing the general arrangement of land districts and lots in Bartow County.

REPRESENTATIVE MINES

BARITE MINES

BARIUM REDUCTION

The Barium Reduction mine, which has been operated by the Barium Reduction Corporation, is in lots 461 and 462, 4th district. It consists of an open-cut 700 feet long, 300 feet in maximum width, and 100 feet in maximum depth.

The geologic structure of the deposit and associated rocks is unusually well exposed. The barite occurs in brown clay residual from dolomite of the Rome formation, and the clay forms a well-defined tabular body, about 70 feet in maximum thickness, which conformably overlies umber residual from hematite of the Shady formation. The umber overlies quartzite of the Weisner formation, which crops out immediately west of the open-cut. The quartzite strikes N. 10° W., and dips about 50° NE. The baritic clay is overlain by weathered, but sharply bedded, white to yellow metashale of the Rome formation containing a few thin beds of quartzite.

Barite also occurs in the umber that underlies the dolomite residuum. The barite in the umber contains rare Archaeocyathid fossils of Shady age. Hull[33] describes a similar but unusually large form from the Bertha mine, which adjoins the Barium Reduction mine on the south.

The Barium Reduction and Bertha mines are in the same body of baritic clay, but the footwall of quartzite of the Weisner formation which is common to both deposits is abruptly offset near the property line that separates the mines. The offset is the result of faulting by which the rocks on the north side moved east about 200 feet with respect to those on the south side. The relation is shown on the geologic map. Jasperoid is abundant in large residual masses in the fault zone but is relatively scarce away from the fault. The solutions that deposited the barite gained access to the dolomite along the fault and spread outward through the dolomite along joints and fractures formed during folding and faulting.

The Barium Reduction mine was opened about 1919 by the Bertha Mineral Co. as a narrow and shallow open-cut about 500 feet long.[34] Except for some prospecting in 1938, the deposit remained unworked until 1940, when the Cartersville Barium Co. began operations. This company produced about 16,000 long tons of concentrates up to September 1942, at which time the Barium Reduction Corp. acquired the mine. Operations were continued by the latter firm, who had produced 24,000 long tons of concentrates up to July 1944. The known output of the mine, therefore, is about 40,000 tons, and the earlier unrecorded output probably did not exceed 10,000 tons.

Recent mining and prospecting have shown that the body of baritic clay pinches out near the north end of the open-cut, reflecting an original lenticular structure of the barite-impregnated dolomite. The continity of the baritic clay down dip, beneath the present floor of the cut, has not been tested. As the baritic clay dips eastward beneath an overburden of metashale, the mining of deeper ore will necessarily involve more and more stripping. A much greater thickness of overburden has already been stripped away than at most of the other barite mines.

BERTHA AND BIG BERTHA

The Bertha Mineral Co. has operated two large open-cut mines in addition to the small mine that served to open the Barium Reduction deposit. The Bertha mine, held by the New Riverside Ochre Co., is immediately south of the Barium Reduction, and overlaps the line between lots 475 and 476, 4th district. The Big Bertha mine is a very large cut that occupies large parts of lots 478 and 531, 4th district; the property that includes all except the north part of the mine is owned by Thompson-Weinman & Co.

The geology of the Bertha mine is identical with that of the Barium Reduction mine, as described above. The mines are located in the same tabular body of baritic clay residual from dolomite of the Rome formation. This body is overlain by metashale containing a few thin beds of quartzite and is underlain by a tabular body of umber, residual from hematite of the Shady formation, resting on thick-bedded quartzite and metashale of the Weisner formation. The Weisner rocks, the tabular bodies of umber and residual clay, and the metashale are conformable and dip east. The residual clay in the Bertha mine is more than 50 feet thick—how much more cannot be determined, because the hanging-wall contact with the metashale is not clearly exposed. The umber appears to be only about 15 feet thick.

[33] Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, pp. 86-87, 1920.

[34] Hull, J. P. D., op. cit., pp. 85, 89.

The Bertha mine was opened in 1914, and was worked on a small scale by hand methods until 1916.[35] The Bertha Mineral Co. carried on large-scale mining with power shovels from 1916 to 1923 and during this time produced 68,000 long tons of concentrates.[36] The mine was idle until 1936, but since that time barite and umber have been mined intermittently by the New Riverside Ochre Co. The production of barite was not recorded apart from that obtained from other mines, but the shipments of umber amounted to about 3,500 tons, and the average grade was about 50 percent Fe and 2 percent Mn.[37] The open-cut is now 1,200 feet long, 100 feet wide, and 90 feet in maximum depth.

The Big Bertha mine is a single large open-cut in baritic clay residual from dolomite of the Rome formation. It lies between ridges underlain by the Weisner formation folded in asymmetrical anticlines (see pl. 1), and the dolomite underlying the baritic clay is undoubtedly folded in an asymmetrical syncline. The presence of the Shady formation at the Big Bertha mine has not been proved, but it probably occurs in normal position between the Rome and the Weisner, as it does elsewhere in the vicinity.

The deposit was first mined in the years 1917 to 1921, from three separate open-cuts.[38] The property was leased in 1921 by the Bertha Mineral Co., who merged the cuts into a single opening and mined continuously to the end of 1929. The mine was again operated by or for this company in 1939 and 1940. The total production of concentrates from 1921 to 1940 was 205,000 long tons.[39] The mine has been operated intermittently since 1940 by the New Riverside Ochre Co., but its production has not been recorded separately. The open-cut is now 1,600 feet long and 80 feet in maximum depth and has an area of about 13 acres.

Although the production of the Big Bertha mine before and after the work of the Bertha Mineral Co. is unrecorded, it is known that the shipments of that company made up by far the greater part of the total output. To obtain some idea of the over-all concentration ratio, it is necessary to estimate the amount of clay removed by the Bertha Mineral Co. alone.

The open-cut has an area of about 575,000 square feet and an average depth, from the original uneven surface of 45 feet; the total volume of material excavated is roughly 850,000 cubic yards. The sketch map of Hull[40] and the observations of the writer indicate that about 700,000 cubic yards furnished the production of the Bertha Mineral Co. The output of 205,000 long tons of concentrates, without voids, would have had a volume of 60,000 cubic yards, and the remainder, 640,000 cubic yards, is the volume of the clay, siliceous boulders, and fine-grained barite lost in milling. This waste weighs about 145 pounds per cubic foot in place, and its total weight would be about 1,118,000 long tons. The combined weight of the barite and the waste was about 1,323,000 long tons, and the overall concentration ratio was therefore 6.5 to 1. It required 3.4 cubic yards of bank ore in place to yield a ton of concentrates, and the bank ore contained 15.4 percent of barite.

CHEROKEE

The Cherokee barite mine, in lot 406, 4th district, is relatively new. It is one of the few mines of any kind, in the Cartersville district, whose entire production has been made by a single operator, and whose history does not involve long periods of inactivity.

The mine is an open-cut about 2¼ acres in extent, immediately west of the old Cherokee ocher mine. (See fig. 13.) The barite occurs in brown clay residual from the weathering of dolomite of the Rome formation. The brown clay is overlain by an uneven mantle of red, sandy colluvial clay, which was found to contain a little barite in places. The residual clay overlies a west-dipping body of bedded ferruginous clay derived from the weathering of hematite of the Shady formation.

The deposit was opened by the Barytes Mining Co. in 1939 and was mined more or less continuously until 1942, when the cut was abandoned, at least temporarily, at a maximum depth of 50 feet. The total output of crude (washed and jigged) concentrates was 45,000 long tons, and the total volume of material mined and stripped was about 130,000 cubic yards. About 2.9 cubic yards of clay was removed, therefore, per long ton of concentrates. There is no record of the weight of the clay mined, but it is estimated to have been 255,000 tons, including the barite. The 2.9 cubic yards containing a ton of concentrates weighed 5.7 tons; thus the bank ore contained 17.5 percent of barite.

No record was kept of the proportion between the amount of clay sent to the log washer and the amount thrown on the dump, but by far the greater part was washed. Regardless of the amount sent to the washer, the approximate over-all ratio given above is regarded by the present operators as satisfactory.

PAGA NO. 1

The Paga No. 1 mine has been operated more or less continuously by the Paga Mining Co. since 1916. Mining was begun in the southeast corner of lot 819,

[35] Hull, J. P. D., op. cit., p. 84.
[36] Information from R. B. Paul, of the New Jersey Zinc Co.
[37] Information from J. R. Dellinger, of the New Riverside Ochre Co.
[38] Hull, J. P. D., op. cit., pp. 101-102.
[39] Information from R. B. Paul, of the New Jersey Zinc Co.
[40] Hull, J. P. D., op. cit., p. 102.

4th district, and was later extended southward into lot 838 and eastward into lots 820 and 837. The main open-cut and a smaller cut immediately to the north have a combined area of 31 acres. They are on the crest and northwest side of a low ridge, and the relief in the immediate vicinity is 200 feet.

The Weisner formation and the carbonate-rock and metashale members of the Rome formation underlie the mine area, and their distribution is shown in plate 16. The carbonate rock here is dolomite, which is covered by an irregular mantle of light-to dark-brown residual clay proved by mining to be more than 150 feet deep in places. The clay was formed, during the deep weathering of the dolomite, by the slumping of the overlying metashale into sinkholes and solution fissures. As a consequence, the contact between the residual clay and the metashale is commonly gradational. Many pinnacles and boulders of the dolomite have been exposed by the mining of the clay, which irregularly contains barite, and the dolomite contains closely spaced bedding laminae of metashale. These are essentially thin layers of fine-grained muscovite schist.

The Shady formation also is known to be present, as Archaeocyathid fossils occur sparsely in umberous clay immediately above the Weisner formation in the extreme northeastern part of the mine. The thickness of the Shady is not apparent, however, and no fossils have been found elsewhere in the mine; the contacts of the Shady, therefore, cannot be accurately traced.

Two long and well-defined faults controlled part and perhaps all of the deposition of barite in the dolomite, and their positions are shown in the geologic map of the mine. (See pl. 16.) Three smaller faults, which are exposed, are also shown. The trace of one of the principal faults extends along the crest of the ridge, in the southern part of the mine. In the southeastern part of the mine, the average strike of this fault is N. 50° E., though it appears to be due east in the southwestern part. In one exposure in the southeastern part the fault clearly truncates thick-bedded quartzite of the Weisner formation, which dips northwest. In another exposure nearby the fault truncates metashale of the Rome formation, which contains thin-bedded quartzite and has diverse dip. These exposures occur where the trace of the fault is shown as a solid line in plate 16. The attitude of the fault plane is not determinable in the exposures, but it appears to be very steep or vertical. At these exposures, and elsewhere throughout its course, the fault zone is well defined by enormous amounts of jasperoid in the residual clay and on the surface. The jasperoid is most abundant within a distance of about 200 feet on each side of the fault, and much of it contains brecciated barite, as shown in plate 13*B*.

The other principal fault, which is in the extreme eastern part of the mine, strikes N. 60° W., and like the one first described is steep or vertical. It has been exposed in a relatively narrow branch of the main cut, which was driven southeastward to the crest of the ridge. When this branch cut was made, its entire northeast wall and bottom, since covered with waste cast from the northeast side, exposed only dolomite pinnacles and baritic residual clay. The southwest wall, however, exposed quartzite of the Weisner formation that strikes northeast and dips northwest. It is evident that the quartzite is cut off and that barite was selectively deposited in the adjacent dolomite, which has subsequently been leached during weathering. The area farther northwest, adjacent to the projection of this fault, may contain most of the recoverable barite that remains in the vicinity of the mine.

Red sandy colluvial clay covers the residual clay in the entire mine area. The thickness of the colluvium is uneven, but ranges from 2 or 3 feet on the ridge southeast of the mine to possibly as much as 100 feet in places along the northwest side.

The total output of concentrates, from the beginning of mining in April 1916 to the end of March 1944, is about 635,000 long tons. The records of the company show 535,000 tons for all of the period except 4 years and 8 months of active operation, of which the records have been lost; the writer estimates that the additional output during this time was about 100,000 tons. The records, unfortunately, do not include data from which concentration ratios can be computed, but the ratios are estimated as follows:

The open-cuts have a total area of about 1,350,000 square feet and an average depth of about 45 feet; the total volume of material excavated is approximately 2,250,000 cubic yards. The output of concentrates, without voids, would have a volume of 190,000 cubic yards, leaving 2,060,000 cubic yards of waste, which consists of clay, siliceous boulders, and fine barite lost in concentrating. The waste would weigh about 3,915 pounds per cubic yard in place, and its total weight would be approximately 3,600,000 long tons. The combined weight of the concentrates and the waste is 4,235,000 long tons. The apparent over-all concentration ratio, therefore, is 6.7 tons, or 3.5 cubic yards, of baritic clay in place per ton of concentrates. The apparent average barite content of all the clay excavated was 15 percent.

PAGA NO. 2

The Paga No. 2 mine, of the Paga Mining Co., is an irregular open-cut in lots 891 and 892, 4th district. The cut has an area of about 9 acres. Much of it has been filled with tailings and erosional debris. Several small open-cuts in the vicinity of the main cut (see pl. 1) are considered in this report to be a part of the Paga No. 2 mine.

The openings are in barite-bearing residual clay containing much jasperoid. The structure of the rocks in general appears to be anticlinal, as dolomite and great masses of bedded jasperoid, which crop out in the adjacent area, dip away from the mine Several pinnacles of the dolomite have been exposed in a small cut 900 feet northwest of the main cut, and one of them contains the lenticular mass of barite shown in plate 14*C*. Another pinnacle in the same cut contains a barite vein 1 to 2 inches thick, exposed for a length of 4 feet.

The mine was opened in 1916[41] and was operated continuously until 1935; mining on a smaller scale was carried on intermittently until 1941 in the small cuts west of the main cut and in the eastern part of the main cut.

The company's records show the output of concentrates for all except 6 years of the operation. The recorded output is 94,111 long tons; that of the period for which there is no record probably is at least 35,000 tons. As the deepest part of the main open-cut is largely filled, it is now impossible to estimate the amount of clay excavated to produce the 130,000 tons, more or less, of concentrates. The cut was relatively shallow, however, and information from persons familiar with the work indicates that the over-all concentration ratio was similar to that of the Paga No. 1 mine.

RESERVOIR HILL

The Reservoir Hill mine is in lot 530, 4th district, a quarter of a mile west of the Big Bertha mine. It is an open-cut, nearly three-quarters of an acre in area and 35 feet in maximum depth. The mine is of interest, not because of its size, but because of its unusually complete record of successful operation. Like the Cherokee mine, it was opened during the past few years and has since been mined by a single operator.

The barite occurs in clays residual from dolomite of the Rome formation underlying the lower east slope of Reservoir Hill. The only bedrock exposed in the vicinity is quartzite of the Weisner formation, which crops out on the low ridge between the Reservoir Hill and Big Bertha mines. The quartzite is folded in an anticline overturned to the west; therefore, the general structure of the dolomite that underlies the clay at the Reservoir Hill mine is probably synclinal.

The introduction of barite into the dolomite may have been controlled by one or both of two faults that trend toward the mine; these faults are shown on the geologic map, plate 1. One of them extends southwest from the Munford mine, and the other extends northwest from the south end of the Big Bertha mine. Owing to the cover of residual clay, there is no positive evidence that either fault extends as far as the Reservoir Hill mine, but the unusual abundance of jasperoid, some of which contains barite, on the adjacent crest of Reservoir Hill is strongly suggestive. It is possible that further mining at the Reservoir Hill mine and at the Clayton mine immediately to the north may follow these apparent trends of mineralization.

The New Riverside Ochre Co. has furnished a record of its operation of the mine from April 1941 to December 1942; the mine was active for 12 months during this period. According to the records, the amount of material excavated was 210,000 long tons. This included 130,000 tons of baritic clay treated in the concentrating plant and 80,000 tons of barren clay thrown on the dump. The total yield, including lump, jig, and table concentrates, was 24,723 long tons of barite.

The over-all concentration ratio was 8.5 tons of clay to 1 ton of concentrates. The ratio between baritic clay and concentrates was 5.26 to 1. The average barite content of all material moved was 11.8 percent and that of the material treated was 19.0 percent. These ratios and grades are relatively good and are probably more closely related to those of earlier mining, which required little stripping, than to those of current mining, which require much stripping because of increasing depth.

SECTION HOUSE

The Section House mine is in lots 751 and 752, 4th district. It is on the east side of a low ridge underlain by quartzite and metashale of the Weisner formation, which are locally folded in a nearly symmetrical anticline. (See the geologic map, pl. 1.) The Weisner rocks dip beneath clay residual from the weathering of dolomite of the Rome formation, and large pinnacles of the dolomite have been encountered in mining.

The dolomite exposed contains a few thin veins and pods of quartz and barite, and small parts of the dolomite adjacent to them have been converted into jasperoid by silicification. The mineralization of the dolomite was controlled by a northeast-trending fault, which cuts off the Weisner rocks abruptly at the south end of the low ridge. Though dip of the fault cannot be determined it is assumed to be vertical.

Most of the early mining was carried on along the south side of the fault, and the northwest side of the cut exposed quartzite so highly fractured that its bedding was hardly recognizable. Recent mining

[41] Hull, J. P. D., Report on the barytes deposits of Georgia: Georgia Geol. Survey Bull. 36, p. 70, 1920.

has extended the cut northwest across the fault, stripping the residual clay from the uppermost quartzite beds, which dip southeast beneath the clay in normal stratigraphic relation. The fault was well exposed in 1941, as shown in plate 9*B*, and at that time the north face of the open-cut was in the fault zone.

The Section House mine was opened in April 1917[42] by Sloan and Peebles, who continued operations intermittently to 1928. The mine was then inactive to 1937. It was operated by Knight and Richards from 1937 to 1939, by Brown and Brown from 1940 to 1942, and by Brown, Dellinger, and Duckett from 1942 to 1944. The total period of operation was about 12 years, but it is very unlikely that the mine was actually in production all that time.

The open-cut made between 1917 and 1928 was 400 feet long, 200 feet wide, and about 70 feet in maximum depth; that cut has been filled with tailings since 1940. The cut made since 1937 is connected with the older cut and extends 400 feet northwestward from it; it is 200 feet wide, and 90 feet in maximum depth.

Thompson-Weinman & Co., who own the property, have recorded an output of 55,549 long tons of concentrates from 1924 to the end of February 1944. Those familiar with the earlier history of the mine believe that this is about half of the total output.

About 178,000 cubic yards of baritic clay have been excavated to produce the recorded output of 55,549 tons. The clay and barite together would have a weight, in place, of approximately 338,000 long tons. The over-all concentration ratio, therefore, was about 6 to 1, indicating a barite content of 16.4 percent for the bank ore whose yield is known.

SLABHOUSE

The Slabhouse mine occupies a considerable area adjacent to the corner of lots 677, 691, and 692, 4th district. The property is owned by Thompson-Weinman & Co. and the mine is operated by the Paga Mining Co. The mine is on a steep slope, drained by a ravine that trends northeastward approximately through the middle of the deposit.

The barite occurs in brown residual clay derived from the leaching of dolomite of the Rome formation. Large pinnacles and boulders of the dolomite have been exposed in mining. The residual clay is covered by a mantle of red, sandy colluvial clay of irregular thickness, which in places contains a little barite derived from the baritic residuum farther upslope. The residuum contains a few angular boulders of jasperoid; the colluvium contains many angular boulders of jasperoid and quartzite and, in its upper part, lenticular bodies of smoothly rounded, water-worn pebbles and boulders.

The quartzite boulders in the colluvium are derived from outcrops of Weisner rocks on the crest of the ridge west and south of the mine. The quartzite in the outcrops west of the mine strikes north and dips east. That in outcrops south of the mine is irregular in attitude, but has in general a westerly strike and northerly dip. The irregularity is most pronounced near a shallow gap in the crest of the ridge, due south of the mine, where there is a small brown-ore prospect. It is believed that the quartzite is faulted in the gap, and that the fault is a continuation of that which has offset the rocks in and near the Paga No. 1 mine. (See the geologic map.) The structure, if correctly inferred, would account for the deposition of barite in the dolomite that has been leached to form the residual clay.

The mine, which was opened in 1917, was leased by the Paga Mining Co. in 1919, and became known as the Paga No. 3 mine.[43] The early mining was confined to the channel and banks of the ravine, in which barite had been concentrated by the erosion of the colluvial and residual clays. The Paga Mining Co. operated the mine, for several years after leasing it and again in 1939, and this work formed an open cut 500 feet long, 270 feet in maximum width, and 50 feet deep. The production of concentrates was not recorded apart from that of other mines that were being operated at the same time.

The property was purchased in 1944 by Thompson-Weinman & Co., and exploration was immediately undertaken by the Paga Mining Co. in the area adjacent to the open-cut. Preliminary work with a portable rotary ("seismograph") drill showed that barite is distributed irregularly in encouraging amounts to depths as great as 100 feet in the residual clays underlying an area at least 1,000 feet in diameter. The area includes the open-cut. The colluvium was found to have an average thickness of about 35 feet, and to contain little barite. It was stripped from most of the area explored, the waste being used in the eastern approach to a new railroad bridge over the Etowah River. At the end of August 1944, stripping was nearly completed, and mining had been started. Additional drilling is contemplated, in order to better outline the bank ore already encountered and for the systematic guidance of open-cut mining. The large size of the area and the depth of the ore-bearing clay indicate that the Slabhouse mine may become one of the largest in the district.

MANGANESE MINES

APPALACHIAN

The Appalachian mine is in the northwestern part of lot 306, 5th district, on the property of W. R.

[42] Hull, J. P. D., op. cit., p. 55.

[43] Hull, J. P. D., op. cit., pp. 63-66.

Hale. It consists of two large open-cuts, immediately east of the numerous workings of the Dobbins mine. The relation of the two mines is shown in plate 17.

The stratigraphy of the Appalachian mine is much like that of the Barium Reduction mine. The manganese and iron oxides occur in an east-dipping tabular body of brown clay residual from the weathering of dolomite of the Rome formation. This body of clay overlies about 30 feet of chocolate-brown umber derived from the weathering of fossiliferous hematite in the Shady formation; residual masses of the hematite occur in abundance on the dump of an old brown-ore cut on the Dobbins property, immediately west of the north Appalachian cut. (See pl. 17.) The hematite and umber overlie quartzite and metashale of the Weisner formation that crop out on the hill west of the Appalachian cuts. The manganiferous clay is overlain by more than 300 feet of weathered white, buff, and pink metashale, also of Rome age, which, prior to weathering, was more or less calcareous.

The manganiferous clay is irregular in thickness. It has its minimum thickness, about 30 feet, in the south end of the south cut, where it dips about 50° E.; it appears to be thicker in and west of the north cut, but there the thickness cannot be measured, because the dip is not evident. This irregularity in thickness may be the result of lenticular structure in the dolomite from which the clay was derived or of intergradation between the dolomite and the overlying metashale. In the west end of the north cut the clay contains large masses of jasperoid in sufficient abundance to suggest the possibility of faulting, but, if a fault is present, the outcrops of the underlying quartzite, which is the only bedrock exposed, are too small and obscure to show its trend.

The manganese is distributed irregularly throughout the brown residual clay in concentrically layered, hard, concretionary masses; it also occurs in and between masses of the jasperoid in veins of loosely coherent, crystalline pyrolusite. Manganese occurs in hard nodules, very irregularly distributed, in originally calcareous parts of the weathered metashale. The concretionary masses and nodules of manganese oxide in the clay residual from dolomite are commonly free from visible iron oxide, but those in parts of the overlying metashale are commonly encrusted with limonite.

The Appalachian deposit was mined on a very small scale before 1908[44] and on a somewhat larger scale in the early twenties. There was no mining of importance, however, until March 1939, when Knight and Beatty leased the property and began developing the south cut. This operation lasted until May 1941, and the resulting output of concentrates was about 1750 tons, containing at least 40 percent Mn.

The lease was then acquired by the Appalachian Manganese Corp., who enlarged and deepened the south cut until slides from the walls made further open-cut mining impracticable; a maximum depth of 120 feet was reached in the north part of the cut. The north cut was then opened and carried to a depth of 70 feet in the west part. The two cuts had a combined area of 2¾ acres when the mine was abandoned near the end of 1942. A shaft 400 feet east of the north cut (see pl. 17.) was sunk in weathered calcareous metashale to a depth of 90 feet, and from the bottom of this shaft a drift was run for 50 feet northwest, where it encountered hard limonite-encrusted manganese nodules and lenses in a zone about 20 feet thick. The metashale containing the manganese strikes northwest and dips northeast. The shaft caved after a small amount of ore had been mined, and another shaft was sunk 90 feet to the northeast, to a depth of 115 feet. This shaft also caved before any appreciable mining was done in it.

About 2,500 tons of concentrates was shipped by the Appalachian Manganese Corp.[45] The output of Knight and Beatty plus the small output from earlier mining would hardly exceed this amount, and the entire output of the mine is about 5,000 tons.

The total amount of clay excavated to produce the concentrates was about 280,000 cubic yards. The weight of the barren residual clay, in place, was carefully determined as 142 pounds per cubic foot, or 3,834 pounds per cubic yard. Even without allowance for any additional weight of ore minerals (see the description of the Aubrey-Stephenson and Bufford mines), the clay excavated weighed at least 479,000 long tons. The over-all concentration ratio, therefore, was not less than 95.8 to 1 by weight. As the greater part of the excavation was done to produce approximately half the total output, there was an extremely wide range in the concentration ratios that characterized the different periods of operation.

AUBREY-STEPHENSON AND BUFFORD

The Aubrey-Stephenson and Bufford mines are the largest manganese mines in the district. The Aubrey-Stephenson group of four open-cuts is in lots 299, 300, and 314, 5th district, as shown in plate 18. The Bufford group of three open-cuts, shown in plate 19, is in lots 300 and 301, 5th district, 1,800 feet south-southwest of the Aubrey open-cut. These mines have been held and operated more or less as a unit by several interests, and their history is so interwoven that they are best described together.

The ores occur in the usual brown clays residual

[44] Watson, T. L., Preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, p. 64, 1908.

[45] From records furnished by R. D. Hale, manager for W. R. Hale.

from the weathering of dolomite of the Rome formation. They consist of hard, concentrically layered nodules of manganese oxide, soft manganiferous clay or "wad", and finely crystalline manganese oxide that encrusts jasperoid boulders. As a result of considerable churn drilling done in 1931, the residual clays in which the manganese occurs are known to be, in places, more than 250 feet deep and to contain numerous pinnacles and residual boulders of dolomite. Such pinnacles and boulders have been exposed by mining in the Little Aubrey, east Bufford, and southwest Bell openings.

The Aubrey and Stephenson cuts are in a linear belt of manganiferous clay, oriented N. 55° E., which also includes two groups of smaller workings, farther northeast, known collectively as the Bell mine. The belt has a total length of at least 3,900 feet. It is straight, whereas the adjacent boundary of the uppermost Weisner quartzite is highly sinuous. (See pl. 18.) The belt of manganiferous clay, therefore, is definitely not a stratigraphic feature, although locally there are layers of manganese oxide parallel to the bedding of the leached rocks.

The lithologic character of the Rome formation in the area that includes the Aubrey-Stephenson deposit is not uniform. The dolomite from which the clay exposed in the Aubrey and Little Aubrey open-cuts was derived directly overlies hematite in the Shady formation, which directly overlies quartzite of the Weisner formation. (See description of the Red No. 2 mine.) The open-cut farthest northeast at the Bell mine, however, exposes manganese-bearing metashale and metasiltstone, calcareous prior to weathering, whose stratigraphic position is equivalent to that of the dolomite at the Aubrey and Little Aubrey cuts.

The Weisner rocks southeast of the deposit are folded into an anticline, which is asymmetrical, possibly overturned to the northwest. The obviously discordant relation between the trend of the deposit and the local contact suggests that the axis of the deposit may be the trace of a steeply dipping fault along which some primary manganese mineral, since weathered to oxides, was introduced into the dolomite. This possibility harmonizes with, though is not necessarily supported by, the occurrence of the hydrothermal minerals tennantite, luzonite, and pyrite in jasperoid and vein quartz at the Aubrey cut (see p. 46) and the occurrence of coarse-grained vein calcite in the factured dolomite exposed in the southwest Bell workings.

Faulting is more definitely in evidence in the Bufford open-cuts. In the southwest part of the south cut, quartzite of the Weisner formation is abruptly cut off on a fault striking N. 50° E. and is in contact with bedded clay leached from dolomite; this fault passes directly through the richest part of the deposit. (See pl. 19.) A northwest-trending fault is also indicated by the truncation of a narrow apparently anticlinal body of the quartzite extending across the middle of the north cut and by an unusual abundance of jasperoid in the adjacent area between the north and east cuts; the jasperoid is veined and coated with crystalline pyrolusite.

The usual overburden of red to yellow sandy colluvium occurs in both the Aubrey-Stephenson and Bufford areas. This colluvium is mostly 5 to 15 feet thick, but on the west side of the east Bufford cut it extends to a depth of about 90 feet. This unusual thickness of colluvium is apparently the result of the accumulation of slope-washed clays in a deep sinkhole (See pp. 24-25.) A stream-channel deposit of water-worn boulders, exposed in the upper northeast wall of the Aubrey cut, records headwater aggradation at the end of Coosa erosion. (See p. 51.)

The property that includes the Aubrey-Stephenson and Bufford mines has been held by at least 12 companies and partnerships prior to the present ownership of J. M. Neel. Large-scale operations in the deposits here described have been confined to three periods; their general results were, in outline, as follows:[46]

During the First World War the Georgia Iron & Coal Co. began the development of the present large open-cuts. It opened the Aubrey cut to a depth of 60 feet, a length of nearly 300 feet, and a maximum width of 150 feet. It also opened the Stephenson cut for a length of 400 feet, and a width of 200 feet; the depth of this cut was not recorded. The north Bufford cut was opened to a depth of 40 feet, a length of 250 feet, and a maximum width of 100 feet. The east Bufford cut was opened to an unrecorded depth, for a length of 200 feet and a width of 100 feet. The mining in those cuts was carried on with six steam shovels, and the ore was log-washed and jigged. The output of concentrates during this period is unknown.

In 1930–31, the Manganese Corp. of America mined the deposits in the largest manganese operation ever attempted in the district, using hydraulic giants. The older cuts, together with some newly opened ones, were developed to the extents shown in plates 18 and 19, except the east Bufford cut, which was only about half its present size when the operation ended. The maximum depth, said to have been 140 feet, was reached in the Aubrey cut, which, however, is now partly filled with tailings.

The sludge from the giants was collected in sumps and pumped to log-washer plants; one plant was at

[46] Condensed from Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, pp. 123-128, 283, 1919.

the Aubrey cuts, and another was at the Bufford cuts. The washed ore was delivered to a dressing plant 1,800 feet southwest of the Aubrey cut, in which the coarser material was jigged and the finer material tabled.

According to records furnished by J. M. Neel, the total output of concentrates from January 1930 to May 1931, which was apparently the entire period of hydraulic mining, was 63,315 tons. It is reported locally that the total output included at least 13,000 tons of table concentrates, containing an average of 28 percent Mn, that were marketed several years after the operation ended. The reported amount of the table concentrates appears to be correct, for the total recorded output from Georgia during 1930 and 1931, which would not include these concentrates, is 49,018 tons, or approximately 14,000 tons less than that of the Manganese Corp. of America during the same period, which would have included them; and the output of this company constituted nearly all of that from Georgia while the operation was in progress.

At the close of this company's operations, the property went into the hands of a receiver. During the receivership, considerable churn drilling was done, from September to December 1931, in the Aubrey-Stephenson and Bufford areas. Holes were drilled 100 feet apart on lines oriented N. 35° W., but the lines were 200 to 750 feet apart—and these intervals are too great to permit the blocking out of ore. Records of the work show that 31 holes were drilled in the Aubrey-Stephenson area; the richest heads from a single hole averaged 11.57 percent Mn and 10.07 percent Fe, and the over-all average was about 2.4 percent Mn and 7.0 percent Fe. In the Bufford area 27 holes were drilled; the highest average metal content of heads was 7.92 percent Mn and 20.36 percent Fe, and the average about 2.2 percent Mn and 7.4 percent Fe. The results of later mining in the Bufford deposit, as given below, show the average results to be expected in selectively mining such ore by present methods.

The records of the exploration also show the results of determining the average weight of the residual clay. Twenty-five samples were taken, at least 10 of them underground, each having a volume, in place, of one cubic foot; the average weight of these samples was 144 pounds. They contained 0.04 to 16.96 percent Mn and 2.77 to 38.74 percent Fe and lost 13.2 to 25.3 percent moisture at 212° F. The writer has found that light-brown residual clay, barren of ore, at the Appalachian mine weighs 142 pounds per cubic foot, and the average given above for the ore-bearing clay is therefore a safe minimum.

The present owner of the property carried on open-cut mining in the east Bufford cut from 1939 to the end of 1943. During this period the cut was enlarged to about twice the extent it had in 1931. A maximum depth of 105 feet was reached in 1941, and mining at this depth was seriously hampered by an abundant inflow of ground water. The ore was log-washed and jigged; the total output was 8,743 tons, dry weight. Mr. Neel has furnished his records of the shipments, which show an over-all range: from 1.75 to 24.46 percent Fe, from 4.74 to 26.41 percent insoluble, from 0.11 to 0.25 (one car, 0.40) percent P, from 2.89 to 14.0 percent moisture, and a content of Mn distributed as tabulated below.

Mn (percent)	Long tons of concentrates (dry weight)	Percent of total weight
17.35 to 20	94.34	1
20 to 25	182.91	2
25 to 30	593.41	7
30 to 35	1,141.31	13
35 to 40	1,415.69	16
40 to 45	4,684.96	54
45 to 47.42	630.20	7
Total	8,742.82	100

This known production from the recent mining in the east Bufford cut provides the only available basis for determining the yield of manganese concentrates from a large amount of residual clay. About 200,000 cubic yards of clay was excavated to produce the 8,743 tons of concentrates. About one-third of this amount was colluvial clay with an average specific gravity of 2.0, and the remaining two-thirds residual clay with an average specific gravity of 2.3. The total weight of all the clay excavated, therefore, was about 667,000 long tons, and the over-all concentration ratio was approximately 76 to 1. As the concentrates were derived from an unkown, but probably small, fraction of 463,000 tons of residual clay, the ratio with respect to the clay that was washed was less than 53 to 1, and probably no more than 15 to 1 owing to selective mining.

BLUE RIDGE (MAYBURN SPRING)

The Blue Ridge manganese mine is 5.5 miles northeast of Cartersville, on lots 274 and 303, 5th district. The property is owned by W. R. Hale. Prior to 1941, lot 303 had been known as the Mayburn Spring lot. The mean altitude at the mine is 970 feet.

Manganese and ferruginous manganese ore occur irregularly, in clays residual from dolomite and metashale of the Rome formation, in the eastern part of lot 274 and the western part of lot 303. Residual boulders of the dolomite have been uncovered on lot 274. The ore-bearing clays occur on the north slope of a west-trending ridge and are underlain by beds of fossiliferous hematite of the Shady formation, which overlie quartzite and metashale of the Weisner formation. The series dips

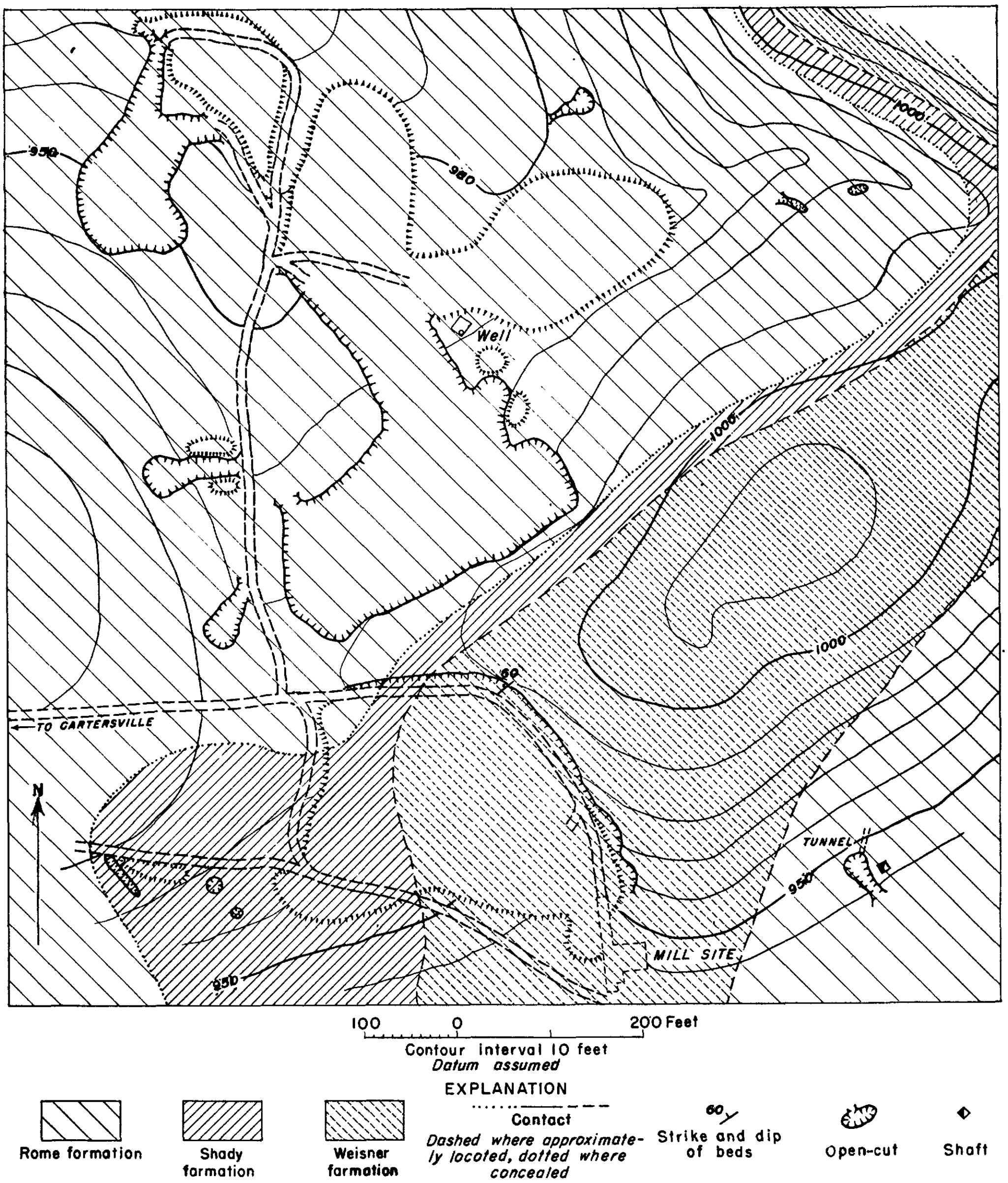


FIGURE 6.—Map of eastern part of Blue Ridge manganese mine.

about 30° NW. The Weisner rocks crop out on the higher ground on lot 303. (See map, fig. 6.) The presence of the hematite is known from persistent float and small prospects, but the beds do not crop out.

The ores in the clay are mixed manganese and iron oxides of nodular and finely disseminated types. The proportions of iron and manganese are highly uneven. Some of the manganese occurs in lenticular and seamlike bodies relatively free from iron, but these bodies appear not to be abundant. The occurrence of the ore shows no consistent relation to the hematite or to the Weisner rocks, nor does it show any trend that might be controlled by geologic structures not apparent in the limited outcrops.

Mining has been carried on intermittently for many years. The dates and results of early operations are unknown, but Watson described open-cut and underground workings made in 1898.[47] The only record of production previous to 1940 is that of Hull who states that two cars of concentrates containing about 40 percent Mn were shipped in 1916.[48]

Since 1940, three successive operators have carried on open-cut mining on a larger scale. The total output of concentrates from these operations is about 1,050 tons of more than 40 percent Mn, and about 2,650 tons of less than 35 percent Mn, mostly less than 30 percent.[49] Of this amount, a final shipment of seven cars was obtained from lot 274, and its average grade was 28 percent Mn.

[47] Watson, T. L., A preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, pp. 65-66, 1908.

[48] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, p. 95, 1919.

[49] Information furnished by R. D. Hale, manager for W. R. Hale, from records of royalties received.

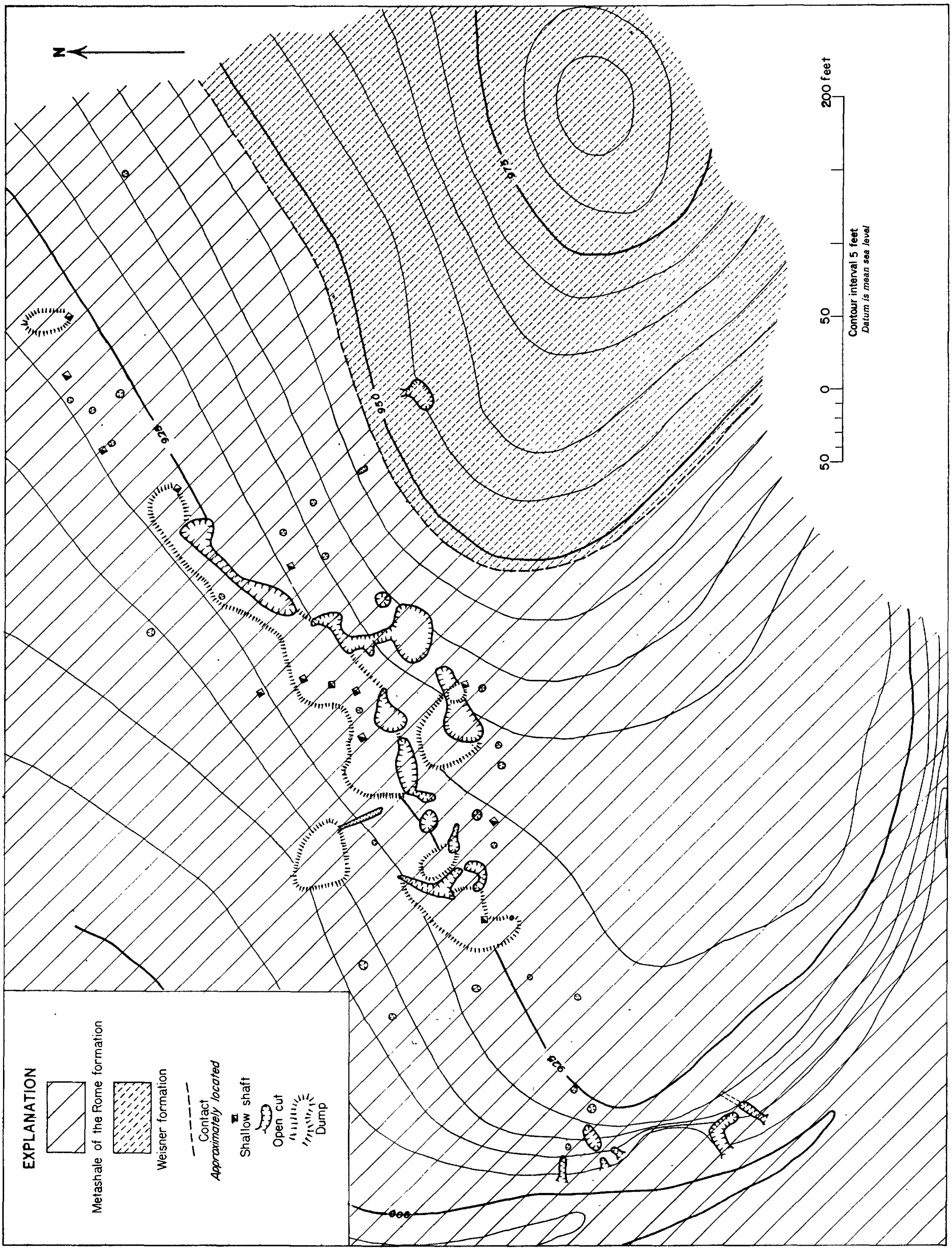


FIGURE 7.—Map of Boneyard mine and vicinity.

Most of the concentrates of more than 40 percent Mn, shipped since 1940, have been obtained from mining in the largest open-cut shown on the accompanying map. (See fig. 6.) The cut is 75 feet deep. Yellow and pink weathered metashale forms the south wall, with the bedding parallel to the adjacent contact of the Weisner rocks; the dip is unevenly northwest. Manganese occurs irregularly in the residual clays, above the metashale, for about 75 feet along the base of the northeast wall, and a prospect pit was sunk into the ore-bearing clay to a depth of 35 feet below the floor of the cut.. Manganese occurs less regularly and in smaller amounts in the southwest part of the cut. A water well was drilled through at least 170 feet of the residual clay on the north side of the cut, and the clay between 140 and 170 feet of depth is said to contain manganese.

BONEYARD

The Boneyard mine is in the southwest corner of lot 180, 22nd district, 8 miles northeast of Cartersville. It consists of a linear group of small openings on the northwest slope of a low knob at an average altitude of 930 feet. (See map, fig. 7.) The property is owned by J. M. Neel.

The knob southeast of the mine is covered by residual slabs and joint blocks of the uppermost quartzite of the Weisner formation. The bedding of the quartzite is not apparent here but is well exposed in equivalent stratigraphic position 1,000 feet southeast of the mine, where the dip is to the west.

The ore-bearing material at the mine overlies the quartzite, and consists of thinly bedded metashale that makes up the lower part of the Rome formation. Hematite beds of the Shady formation and dolomite of the Rome formation, which commonly overlie the Weisner rocks, are not present in this area.

The metashale near the surface is white to buff and is thoroughly weathered. That removed from the deeper mine openings is light gray; it has been leached by ground water but is not so highly weathered as the metashale nearer the surface. The rock appears to have been calcareous prior to weathering. Manganese oxide occurs in the metashale in random thin lenticular nodules mostly less than 6 inches long, oriented parallel to the bedding. The nodules are thinly layered, and the layers also are parallel to the bedding of the enclosing metashale. Many of them contain laminae of the metashale between the layers, and these laminae are partly replaced by the manganese. Some of the nodules consist essentially of metashale highly impregnated with manganese.

The manganese has clearly replaced the metashale during the process of weathering. As the bedded structure passes through the nodules without interruption, the manganese obviously was not derived from the weathering in place of primary manganiferous nodules. The manganese oxide was transported and deposited by ground water, but the source is not apparent. Much of the quartzite southeast of the mine is highly fractured and impregnated with limonite, but outcrops are too scarce to infer a genetic relation between the limonite and the manganese oxide.

The manganese is dense, relatively soft, and has a dull luster; none of it occurs in crystalline form. Qualitative chemical tests made by Michael Fleischer in the chemical laboratory of the Geological Survey, show that potash and barium are absent. It is concluded that the mineral is pyrolusite.

The Boneyard deposit is not mentioned in earlier reports, but small-scale "groundhog" mining has been carried on intermittently for many years up to 1942. The ownership of the property has changed several times during this period, and no record of the output of the mine has been kept. The total may be about 1,500 tons. Analyses of two cars of concentrates shipped in 1940 show an average of 49.86 percent Mn, 2.2 percent Fe, 8.10 percent insoluble, 0.35 percent P, and 6.0 percent moisture.

CHUMLEY HILL-RED MOUNTAIN

The Chumley Hill-Red Mountain manganese deposit has an unusual length of nearly three-quarters of a mile. It occurs in lots 143, 144, 145, 146, and 147, 22nd district, east of the Aubrey-Stephenson mines, and contains the Chumley Hill, Moccasin, and Red Mountain mines, whose locations are shown in plate 18. Little is known about the operation of the mines, and even less about the production, but the size of the deposit gives it potential importance.

The manganese occurs mostly in concentrically layered nodules and consists of both massive and crystalline oxides. The nodules occur with much residual jasperoid in clay formed by the weathering of dolomite of the Rome formation; the association is identical with that at the Aubrey-Stephenson mines to the west. The clays occur in a relatively narrow belt, associated with metashale of the Rome formation, between low ridges underlain by Weisner rocks. (See pl. 18.) The uneven distribution of the residual clay and weathered metashale in this belt illustrates unusually well the characteristic lenticular relation of the lower Rome rocks.

The deposit is interesting not only because of its size but also because the occurrence of the manganese is known to have a vertical range of at least 280 feet. The lower limit of the oxide ore has not been reached, but drilling has proved its presence at the Chumley Hill mine to a depth of 100 feet (altitude 920 feet), and the ore-bearing residuum is continuous to an altitude of 1,200 feet on the southeast side of Red Mountain. A prominently exposed fault zone, traced by outcrops of highly brecciated quartzite impregnated with limonite, intersects the belt of ore-bearing clay at the Moccasin mine. Similar brecciated quartzite occurs on the slope above the western Red Mountain workings, and the less-weathered rock contains abundant pyrite.

It might be inferred that the continuity of the manganese deposit parallel to the strike of the formations is evidence that the dolomite contained syngenetic manganese prior to weathering. It can also be inferred, however, that the dolomite contained epigenetic manganese introduced along the fault and distributed laterally along joints and fractures in the dolomite. The abundance of jasperoid throughout the deposit indicates that hydrothermal quartz was distributed widely throughout the carbonate rock.

The ore-bearing clays that underlie the steep south slope of Red Mountain are well drained, but the western part of the Red Mountain workings merge with those of the Moccasin mine where ground water stands almost at the surface in wet seasons. A narrow stream valley has been cut in the residual clays between the Moccasin and Chumley Hill mines, and the stream maintains the high level of ground water. Shallow prospecting, undertaken during unusually dry summers, has shown that the clays are unevenly ore-bearing, but mining methods heretofore employed cannot be used for large-scale operations in this sector of the deposit.

The Chumley Hill mine consists of an open-cut, 50 feet deep and nearly 400 feet long, oriented north, and a smaller cut 15 feet deep and 200 feet long, oriented east; the larger cut is partly filled with eroded debris. The date of the earliest mining is unknown, but openings had been made at both the Chumley Hill and adjacent Moccasin deposits before 1886.[50] The Chumley Hill deposit was mined by Munford and Akin, in 1904-05, by an inclined tunnel that reached a maximum depth of 50 feet. George F. Hurt developed the open-cut in 1906; he also extended the underground workings to a maximum depth of 149 feet below the original surface.[51] Eleven published analyses[52] of concentrates believed to have been produced from the Chumley Hill mine show an average content of about 39 percent Mn.

The smaller Chumley Hill cut was made about 1934 by T. B. Holmes who also sank a shaft to a depth of 95 feet on the north side of the cut. The shaft failed before any underground mining was done, and there is no record of the output from the cut. Holmes also drilled eight holes in this area, but the exact locations are not recorded. The holes ranged from 27 to 120 feet in depth. The logs show a highly uneven occurrence of manganese; the recorded assays of bank ore from five of the holes show a range in grade from 2.14 to 29.98 percent Mn, and the weighted average grade is 7.21 percent Mn.

The Moccasin mine consists of a group of coalescing pits and shafts 375 feet in length. The pits are partly filled with alluvium, but Hull[53] reported that one of the cuts was originally 50 feet deep and that a shaft was sunk 40 feet below the bottom; he gives also an analysis of the ore made by the Georgia Iron & Coal Co., a former owner of the property, which shows 44.60 percent Mn, 11.42 percent Fe, and 0.478 percent P. There is no definite information regarding the dates of the mining or of the output.

The Red Mountain mine consists of a linear group of pits, tunnels, and shafts that extends from the slope 350 feet north of the Moccasin mine eastward for a distance of 1,700 feet along the south slope of Red Mountain. The eastern part of the workings are on lot 147 and are sometimes referred to as the Allison mine. Most of the openings are adjacent to the uppermost beds of quartzite of the Weisner formation, where the ore-bearing residual clay is covered only by very thin soil; float ore obviously encouraged mining here. The residual clay that underlies the steep slope south of the workings is covered by colluvial overburden and has not been adequately prospected. The dates of operation and the output of concentrates are unknown.

DOBBINS

The Dobbins mine consists of a large number of open-cuts and inaccessible underground workings in lot 271, 5th district. The Alabama-Georgia Mining Co. owns the property. Plate 17 shows the extent of the workings and the relation of the Dobbins to the adjoining Appalachian mine. The areal geology is shown insofar as it could be mapped, but it is known imperfectly because thick colluvial clay covers most of the bedrock and residual clay.

The stratigraphy of the rocks that underlie the property is equivalent to that of the rocks underlying the Appalachian property. The oldest rocks exposed are quartzite and metashale of the Weisner formation, which crop out on the hills northwest and northeast of the main workings. The Weisner rocks are overlain by hematite and interbedded dolo-

[50] Willis, Bailey, Notes on the samples of manganese ore collected in Georgia: U. S. Geol. Survey 10th Census, Vol. 15, p. 381, 1886.

[51] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., pp. 128-129.

[52] Weeks, J. D., Manganese: Mineral resources U. S., 1886, p. 186, 1887.

[53] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., p. 150.

mite of the Shady formation, which for the most part are weathered to umberous clays.

Umber and brown iron have been mined from the weathered Shady beds in the extreme northeast corner of the lot. The dumps there contain fossiliferous hematite that is only partly hydrated to limonite. The inclined tunnel shown on the map was accessible in 1939, and the workings showed that the structure of the beds is anticlinal. The crest of the fold coincides with the north-oriented nose of the hill and plunges northward at about 10°. The beds in both limbs dip away from the crest at an initial angle of about 15°. The low angle of dip, in contrast to that in the south cut of the Appalachian mine, accounts for the divergence of the contacts shown on the map, and the thickness appears to be more or less uniform, or about 30 feet.

The upper contact of the Weisner formation is on the crest of the ridge that extends southwest from the Dobbins mine (see pl. 17), and limonite float is persistent along the contact. The limonite has been mined 0.6 mile southwest of the west Dobbins cut, beyond the limits of the area mapped. The opening exposes the partly hydrated hematite of the Shady formation in place, and the continuity of limonite along the contact indicates that the Shady is continuous northeastward to the Dobbins.

Colluvial overburden and the rapid slumping of open-cut walls prevent the mapping of the Shady formation in most of the Dobbins mine area. The formation is shown on the map only where residual limonite and fossiliferous jasperoid indicate its presence along the upper contact of the Weisner formation. There is little doubt that the hematite is present in this position throughout the mine area, and that, through weathering, it has furnished the high proportion of iron that a large part of the Dobbins ore contains, as stated below.

The Shady formation is overlain by dolomite of the Rome formation, which in the zone of weathering has been leached to brown residual clay that contains unevenly most of the manganese. Exposures of the residual clay at the Appalachian mine show that the dolomite does not have uniform thickness. (See p. 68.) This condition appears to apply to the Dobbins area as well, but the exposures do not show the range of thickness. The contacts shown on the map are approximate for this reason.

The dolomite is overlain by well-bedded metashale of the Rome formation, which originally was quite variably calcareous. The more highly calcareous parts are leached to light-brown bedded clay similar to much of the unbedded clay residual from the underlying dolomite. These leached calcareous beds in places contain manganese. The less calcareous parts of the metashale are also strongly weathered but are white, buff, and pink in color and contain a few random beds of quartzite. Most of the quartzite beds are from less than 1 inch to 2 inches thick, but a few of the beds in the metashale along the south side of the west cut are a foot or more thick.

The major geologic structures in the mine area are two anticlines and a fault. The anticlines underlie the hills northwest and northeast of the main workings, where the Weisner formation is exposed, and the folds plunge north. The Weisner rocks are cut off abruptly on the south slopes of the hills by a fault that trends N. 65° E. The fault is clearly exposed in the two east cuts (see pl. 9*A*) where the Weisner rocks strike obliquely against manganiferous clay residual from dolomite of the Rome formation. The dip of the fault is not determinable but appears to be steep. An old stope at the east end of the cuts slopes northeast; this may indicate the dip of the fault, or it may indicate only a local irregularity.

The localization of manganese ore along the south side of the fault, and in the adjacent area, suggests the same genetic relation between faulting and primary ore deposition that characterizes the barite deposits. This cannot be proved, however, as the manganese oxides are supergene, and their origin involves at least one more process than is involved in the origin of the residual barite.

The manganese occurs irregularly in the clays residual from the dolomite and the calcareous parts of the metashale. The clay residual from the dolomite is the principal source of the ore. The manganese occurs unevenly in hard, concentrically-layered concretions and in fine-grained, wadlike mixtures with clay. It is associated with rather high proportions of limonite and umber, which also occur unevenly. The iron oxide appears to be most abundant near contacts with the Weisner rocks, and further indicates the presence of hydrated hematite of the Shady formation where the formation is not definitely recognizable.

As the distribution of the mine workings indicates (see pl. 17), residual clay containing encouraging amounts of recoverable manganese and iron oxides is unusually abundant. Experience has shown, however, that concentrates produced by mass mining, with current methods of concentration, are for the most part ferruginous. Most of the output of concentrates containing more than 35 percent Mn has been obtained from underground mining in which ore containing objectionable amounts of limonite was rejected.

There has been more underground mining than is apparent on the map. Some shafts have been obliterated by recent open-cut mining, and only those still recognizable are shown. It will be noted on the map that a number of the shafts have exceeded 100 feet in depth. The original Dobbins, or "sand", shaft

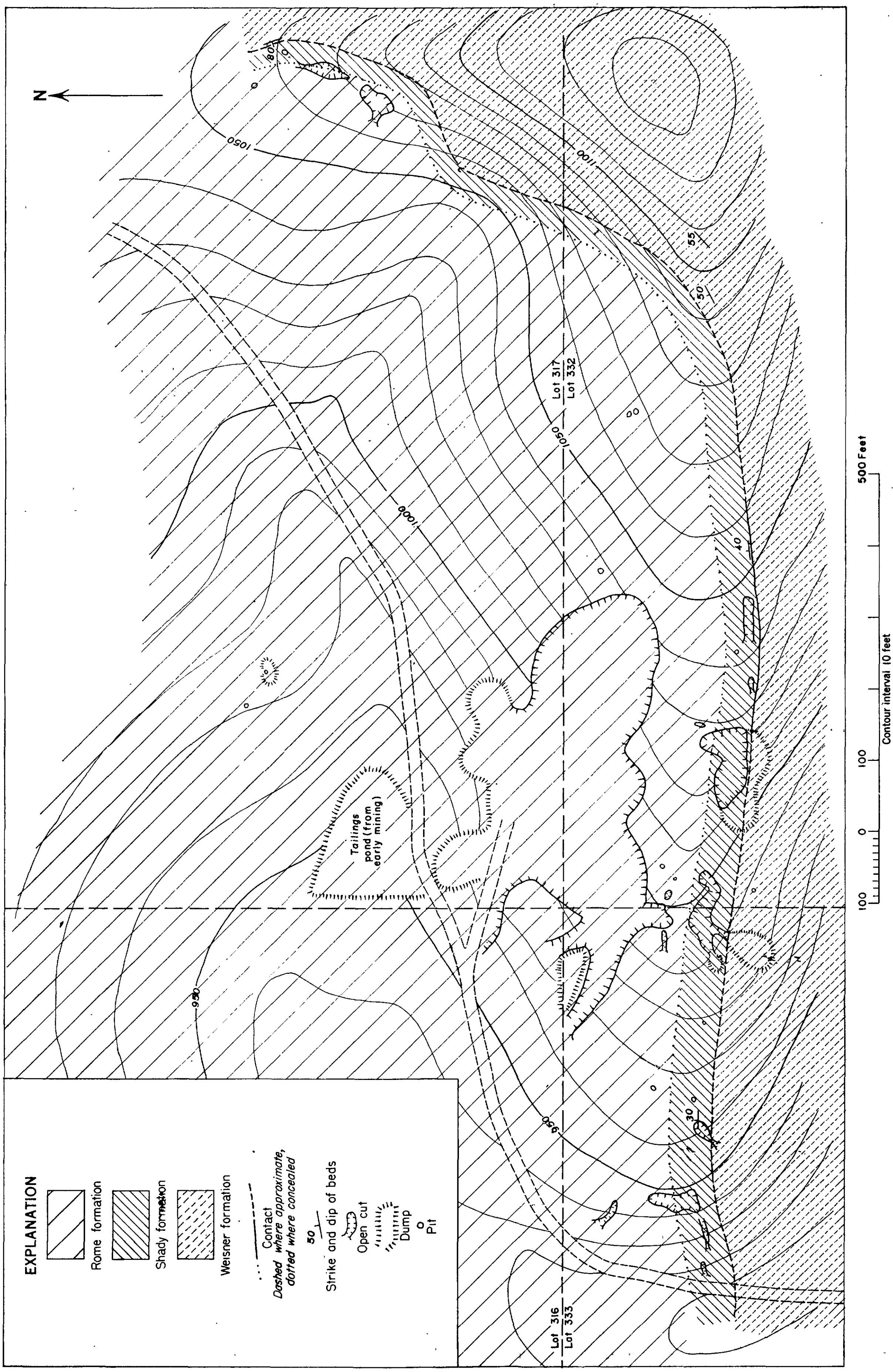


FIGURE 8.—Map of Howard manganese mine and vicinity.

is reported to have reached, during the nineties, a depth of 210 feet, in ore.[54]

Little ground water has been encountered even in the deepest of recent shafts. This feature, which is favorable for deep mining, is the result of the relatively high altitude of the mine and the lack of closed, synclinal structure of the rocks that underlie the clays. Ground water is drained away from the mine area into the clays underlying adjacent lower areas. The dolomite, leached to an unusual depth by the rapid migration of the ground water, has not been encountered in any of the workings.

Hull[55] reports that the Dobbins mine was opened in 1866 and that mining was carried on more or less consistently until about 1896. It was mostly underground work. It appears that only small-scale, intermittent mining was carried on from 1896 to 1916, when the Republic Iron and Steel Co. began the development of what is now the west cut, and did considerable underground mining from an incline whose mouth is shown on the map; this operation lasted about 3 years. The bearing of the incline was N. 30° W. and the slope about 45°. It is said to have been 284 feet long with lateral tunnels, most of which were driven northeast to the adjacent contact with quartzite of the Weisner formation.

Hull[56] estimated that at least 15,000 tons of concentrates containing more than 40 percent Mn were produced before the Republic operation and that about 7,500 tons of concentrates containing less than 20 percent Mn were produced during the Republic operation.

Relatively small-scale mining was carried on intermittently by various operators from 1919 to 1937; most of the work was done between 1919 and 1929. The property was purchased by the Alabama-Georgia Mining Co. in 1937, and mining was carried on almost continuously until 1942. During this period, the north cut and the two east cuts were opened, the west cut was enlarged and deepened, and at least nine shafts deeper than 75 feet were sunk in the adjacent areas. These operations were devoted largely to the production of ferruginous manganese, but some manganiferous umber was mined from a shallow incline west of the north Appalachian cut. The total output was about 10,000 tons of concentrates containing an average of 17 percent Mn and 30 percent Fe, and about 6,000 tons containing about 26 percent Mn and 24 percent Fe.[57]

There has been very little production of concentrates containing more than 35 percent Mn since 1919, and Hull's estimate of 15,000 tons seems liberal enough to cover the life of the mine. The known output of concentrates containing less than 35 percent Mn is approximately 23,500 tons. It is not likely that the small-scale production of which there is no published or unpublished record would bring the total output of this grade to more than 28,000 tons. It appears, therefore, that about 43,000 tons of concentrates of all grades have been shipped from the Dobbins since 1866. Owing to the comparatively large extent of the underground workings from which much of the ore was mined, and to the inaccessibility of these workings, it is impossible to determine the concentration ratio of all or any part of the output.

HOWARD

The Howard mine is 1.5 miles northeast of Cartersville, in the 4th land district. It consists of a large, irregular open-cut and smaller openings in a ferruginous manganese deposit that underlies an area of about 6 acres in the northwest corner of lot 332, the southwest corner of lot 317, and the northeast corner of lot 333. The map (fig. 8) shows the location of the mine openings with respect to the lot lines. Lots 317 and 332 are the property of the New Riverside Ochre Co., and lot 333 is owned by the Cherokee Ochre Co. The average altitude at the mine is 1,000 feet, and the relief is 130 feet.

The manganese deposit occurs, in clays residual from the weathering of dolomite of the Rome formation, on the north slope of a ridge that trends westward. As shown on the map, the uppermost beds of the Weisner formation crop out along the crest of the ridge. The Weisner rocks dip northward at an average angle of 35° beneath the clay. The Shady formation is present immediately above the Weisner, but the beds are so weathered near the surface that they do not crop out. The presence of the Shady is known from quartz-replaced fossils that occur in the residual clay along the crest of the ridge, and the presence of hematite beds is strongly suggested by the abundance of limonite, some of which was mined many years ago, and thinly bedded umber adjacent to the upper contact of the Weisner formation.

The residual clay underlying the north slope of the ridge is light to dark brown. It contains very irregularly distributed masses of jasperoid as much as 5 feet thick and bodies of intermixed manganese and iron oxides that range from a fraction of an inch to a foot thick. Locally, as in the east wall of the main open-cut, the ore is high-grade manganese of psilomelane type.

The residual clay is covered by a layer of colluvium, which is about a foot thick on the crest of the ridge and which thickens downslope to about

[54] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., p. 109.

[55] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., pp. 104-105.

[56] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., op. cit., p. 111.

[57] Information from C. H. Claypool, superintendent of the mine.

30 feet at the entrance to the main cut. Near the crest of the ridge the colluvium consists of deep red, sandy clay containing a few semirounded boulders of quartzite, but downslope the boulders are progressively more abundant and more rounded, and the matrix of sandy clay is mottled red and white. The mottled clay is locally known as "calico clay." Besides the abundant boulders of quartzite, the "calico clay" also contains rounded masses of jasperoid and ore similar to the ore in the underlying residual clay.

The colluvium accumulated on the slope during a period of very rapid erosion, for none of it is stratified. As the elevation of the mine corresponds to the headwater altitude of the Coosa terrace, the colluvium evidently accumulated during the dissection of residual clays of the Highland Rim peneplain. The occurrence of abraded masses of ore in the colluvium shows, therefore, that at least a part of the manganese and iron oxides were formed or deposited in the residual clays not later than the close of Highland Rim planation. (See discussion of erosional history, pp. 50-51.)

The pits adjacent to the contact, which are shown on the map, were made many years ago, and the output of ore is unknown. Brown iron ore was mined from the pits immediately south of the large open-cut, and ferruginous manganese from those on the west nose of the ridge.

The large open-cut has been made by intermittent mining from 1940 to the summer of 1944. In 1940, according to records of the New Riverside Ochre Co., Knight and Richards produced 1,126 tons of concentrates, which averaged 20.25 percent Mn and 19.78 percent Fe, from that part of the deposit in lot 332.

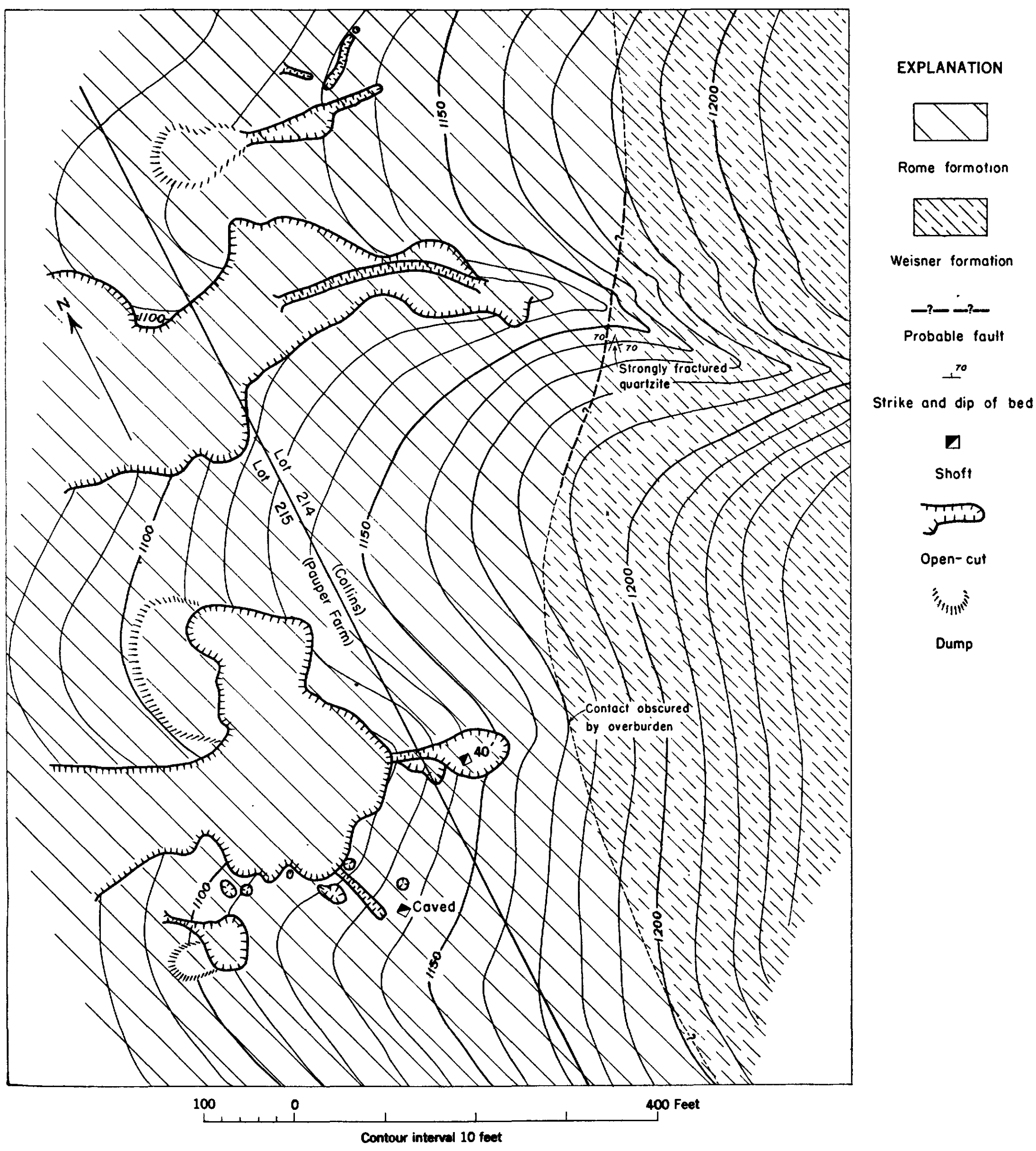


FIGURE 9.—Map of the Pauper Farm-Collins manganese mine.

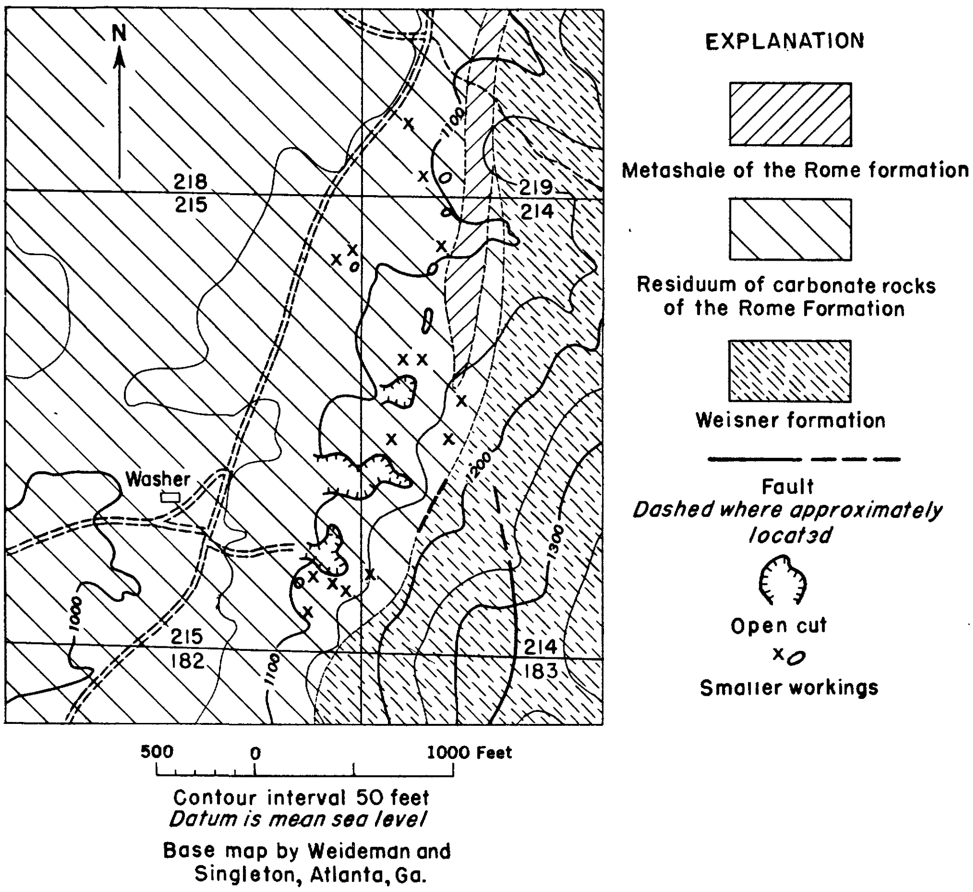


FIGURE 10.—Geologic, topographic, and land-lot relations of the Pauper Farm-Collins manganese deposit.

About the same time, the Barytes Mining Co. produced a few cars of concentrates from the part in lot 333.

The New Riverside Ochre Co. began mining on lots 317 and 332 in July 1943. Through May 1944 the company produced 1,163 tons of concentrates, ranging in grade from 16.7 to 33.5 percent Mn, from 36,446 cubic yards of bank ore.[58] The weight of the bank ore was about 60,000 tons. The concentration ratio, therefore, was 51.6 tons of ore-bearing clay to 1 ton of concentrates.

PAUPER FARM-COLLINS

A belt of manganese-bearing clay, more than one-half mile in length, occurs at the western base of Little Pine Log Mountain, 9.5 miles northeast of Cartersville, in lots 214, 215, and 219, 22nd district. Lot 214 is known as the Collins lot, lot 215 as the Pauper Farm lot, and lot 219 as the Hogpen lot. The greater part of the deposit is in the western part of the Collins lot and the eastern part of the Pauper Farm lot at a mean altitude of 1,100 feet. (See fig. 10.)

The clay that contains the manganese is residual from the weathering of dolomite of the Rome formation; the dolomite crops out through the clay 500 feet northeast of the washer shown in fig. 10. Metashale of the Rome formation underlies the area west of the residual clay. On the east side of the ore-bearing clay, the erosionally resistant quartzite and metashale of the Weisner formation underlie Little Pine Log Mountain. The crest of the mountain coincides more or less with the crest of an anticlinal fold, as shown by the structure symbols on plate 1, but the rocks exposed on the western slope dip east, and the anticline is evidently overturned toward the west.

The contact between the ore-bearing clay and the Weisner rocks is exposed at only one place along the eastern side of the ore deposit. (See fig. 9.) At that place, the uppermost quartzite is highly fractured, and the fractures are partly filled with limonite. As shown on the map, the beds have sharply opposed attitudes as a result of faulting. The trend of the fault appears to be parallel to the contact with the ore-bearing clay, but it cannot be traced nor can the contact be mapped accurately beyond the exposure because of colluvial overburden that covers the slope.

The colluvium consists of unstratified yellow sandy clay containing abundant rounded pebbles and boulders of quartzite up to 18 inches thick. This material was derived from the rapid erosion of the Weisner rocks probably during the dissection of the

[58] Information furnished by the New Riverside Ochre Co.

Highland Rim peneplain. The debris also covers the ore-bearing clay unevenly.

The ore-bearing clay is brown, and it contains angular and unevenly distributed boulders of jasperoid. Quartzite boulders occur in the uppermost part of the clay where they have apparently been buried by the subsidence resulting from solution of the underlying dolomite. Iron and manganese oxides mixed in various proportions occur quite irregularly in the residual clay; both occur in nodular masses as well as finely disseminated, "soft" ore. Much of the nodular manganese contains small fragments of glassy vein quartz and white jasperoid, and these are abundant enough in the ore at places to interfere with concentration.

Mining on the Pauper Farm and Collins lots was started before 1908. Watson[59] described an open-cut 200 feet long and 50 to 75 feet wide on lot 214, which is probably the long cut shown in figure 9. Operations on lot 215, but not the production, are recorded[60] for the Republic Iron & Steel Co. in 1917 and the Carribee Mining Co. in 1918. These operations were confined mostly to the positions of the two large open-cuts shown in figure 9. The north cut was deepened during a short period of mining by T. B. Holmes about 1933; the cut is 50 feet in depth, and is the largest opening in the Pauper Farm-Collins area. The total output of concentrates from the two lots up to 1943 is unknown, but probably it does not exceed 5,000 tons.

Considerable prospecting was done in 1943 by the White Mining Co. in the southeast part of lot 215 in the area shown in figure 9. Short tunnels were driven into the walls of the south open-cut, and the walls were cleaned off by power shovel. The company completed a washer in May 1944 and has produced about 350 tons of concentrates to August 15; the maximum grade per car is 37 percent Mn. The clay in the bottom and lower east wall of the south cut contains unevenly disseminated manganese. The wall has an average height of 35 feet, and there is apparently a considerable reserve of bank ore available. Arrangements have been made to extend the mining eastward into lot 214 if the ore is continuous in that direction.

Lot 214 is leased to W. S. Knight who produced a few hundred tons of hand-mined soft ore during 1943 and 1944 for the use of the Cartersville plant of the Burgess Battery Co. The ore contains an average of 30 percent Mn and is not washed. Part of the ore has been mined from the northwest part of the lot, where the openings expose residual clay that contains an unusually high proportion of nodular and finely disseminated manganese. The continuity of the deposit is concealed by colluvial overburden. There appears to be a considerable reserve of ore in this area, but operations heretofore have been hampered by ground water, which is encountered at an average depth of 30 feet in summer and at shallower depth in winter.

[59] Watson, T. L., A preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey, Bull. 14, p. 75, 1908.

[60] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, p. 318, 1919.

WILL LEE

The Will Lee mine is in the eastern part of lot 276, 6.5 miles northeast of Cartersville, on the property of J. M. Neel. The mine is on the north slope of Bufford Mountain at an altitude of 950 to 980 feet. It is locally noted for the relatively large proportion of concentrates produced from underground mining, but the deposit is now being mined by open-cut method.

The mine area is underlain by the Weisner, Shady, and Rome formations, which are deeply weathered. There are no outcrops, owing to the presence of a surficial blanket of red sandy colluvial clay 2 to 19 feet thick. Geologic contacts are known only approximately; consequently, the structure is obscure. The only exposures of bedrock and its weathered residuum are in the mine and prospect openings. The topographic setting and the general distribution of formations are shown in figure 11.

The manganese occurs in a body of brown clay residual from the weathering of dolomite of the Rome formation. This body strikes about N. 50° E. and dips northwest and was proved continuous to a vertical depth of more than 180 feet in 1931 by churn drilling undertaken by the Manganese Corp. of America. Dolomite was encountered in two of the churn-drill holes. The ore-bearing clay is stratigraphically overlain and underlain by strongly leached light yellow calcareous metashale, whose bedding is parallel to the contacts.

Quartzite and metashale of the Weisner formation are exposed in three prospect shafts east of the mine. Specular-hematite float is abundant in the colluvial overburden on the low ridge due south of the No. 1 shaft site (see fig. 11), indicating the presence of the Shady formation between the Weisner and the Rome formations. The weathered bedded hematite was prospected in place many years ago, 450 feet south-southeast of the No. 1 shaft site; two shallow pits were opened. Most of the hematite at shallow depth is hydrated to umber, but some high-grade residual hematite ore was found. The beds at the prospect strike northeast and dip northwest, but the known position of Weisner rocks to the north makes it appear that the trends of the Shady formation and of the body of manganiferous residuum are divergent.

This conclusion is substantiated by the fact that

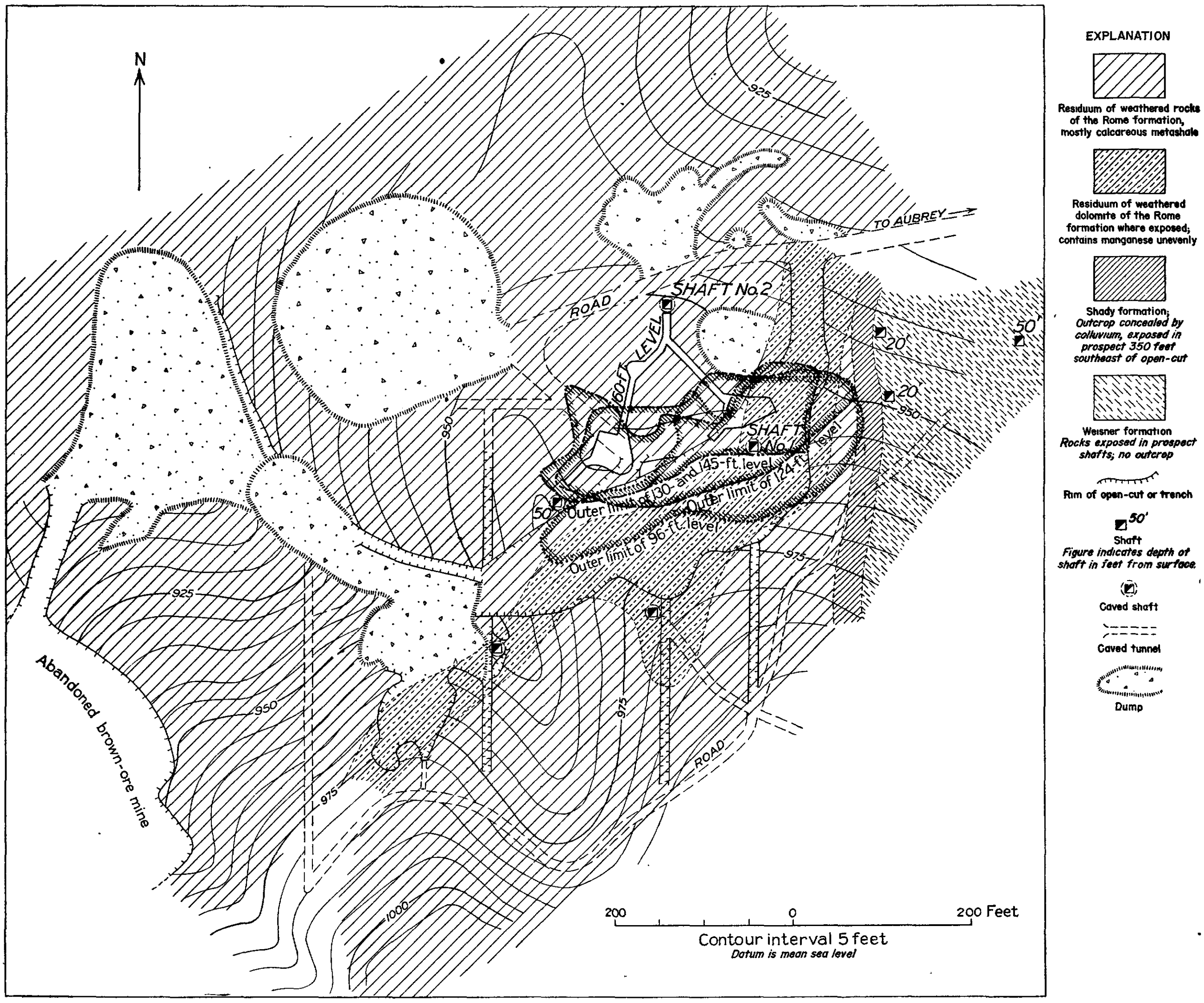


FIGURE 11.—Map of Will Lee manganese mine.

the metashale, which occurs between the manganiferous residuum and the hematite of the Shady formation is very thin at the northeast end of the mine but is more than 100 feet thick at the southwest end. The oblique truncation of the metashale might be the result of lenticular deposition, but this would not explain the apparent divergence of bedding, as there is no unconformity elsewhere in the district between the Weisner and the Rome formations. It seems more likely that the truncation is the result of faulting and that the fault plane locally may be more or less parallel to the contact between the Shady and the Rome formations.

The manganese oxide in the body of clay residual from dolomite is concretionary, and many of the concretions are 6 inches or more thick, consisting of concentric layers of both massive and crystalline oxides. Chemical and X-ray tests[61] have shown that both types of the manganese are pyrolusite. Limonite accompanies the manganese unevenly; it occurs as crusts on, and thin layers in, the manganese concretions, and in irregular bodies that contain little or no manganese. Jasperoid also is present unevenly in the ore-bearing clay, particularly in the northeast part of the deposit. It is reported by local miners that manganese stalactites as much as a foot in length were found at depth in open crevices in the jasperoid.

The Will Lee deposit is not mentioned in earlier reports on the district. The earliest mining was carried on by Will Lee, probably in the early twenties, to depths mostly less than 50 feet.

In 1931, the Manganese Corporation of America, in receivership, sank 10 exploratory churn-drill holes in the vicinity of the mine. This work proved the northwest dip of the deposit and provided some guidance for the underground mining that was later carried on. The holes drilled were from 100 to 230 feet deep. The records show that bank ore of the highest grade contained 14.65 percent Mn and 10.90 percent Fe and that the average grade was about 4 percent Mn and 14 percent Fe.

[61] By Michael Fleischer and Joseph Axelrod.

Underground mining was carried on in 1934 and 1935 under the supervision of T. B. Holmes. Two shafts were sunk, and six levels developed. (See fig. 11.) Records of the operation indicate that the No. 1 shaft was 145 feet deep, with levels at 50, 96, 124, 130, and 145 feet and that the No. 2 shaft was 160 feet deep, with a level at that depth, which had been developed to only a limited extent when the mine was abandoned late in 1935. The output of concentrates from the underground mining is locally reported to have been 10,000 tons. Records of a substantial part of the shipments show a grade of 38 to 44 percent Mn.

The underground workings were inaccessible during the writer's field work, but Holmes' plans of the levels indicate that about 175,000 cubic feet of bank ore was removed in mining. A ton of the bank ore in place has a volume of about 15.5 cubic feet, and the volume mined, as indicated by the plans of the levels, would weigh about 11,000 tons, or little more than the washed and jigged concentrates. It is obvious, therefore, that the plans of the levels show the drifts and crosscuts, but few of the stopes. For this reason, figure 11 shows only the outer limits of the levels except that at 50 feet, which was too small to be indicative. The levels reflect the northwest dip of the deposit, which in general appears to be about 55°, except at the extreme northeast end where it may be steeper.

Open-cut mining was started by Neel and Neel in January 1944. Before August 15 the cut was 450 feet long, and the maximum depth was 50 feet opposite the crest of a low ridge on the south side.[62] The output of concentrates, as of the same date, was approximately 900 tons, of which 250 tons contained 35 percent or more Mn and the remainder less than 35 percent Mn. The total content of manganese and iron is 50 to 55 percent. The iron is present in limonite, which appears to have been deposited by ground water that sinks through the colluvial overburden containing specular hematite. Limonite may be less plentiful with increasing depth below the colluvium, a possibility which agrees with the higher grade of concentrates obtained from ore previously mined underground.

BROWN-IRON MINES

BARTOW GROUP

The Bartow iron mines consist of four large open-cuts in land lots 901, 902, 903, 904, 969, 970, and 971, 4th district, near the village of Bartow. (See pl. 1.) These cuts have a combined area of about 9 acres. Several smaller and older cuts have been filled with tailings.

[62] The Will Lee open-cut reached a maximum depth of 111 feet in October 1945.

The No. 1, No. 2, and No. 3 cuts have been made in limonite-bearing material, residual from the weathering of Rome rocks, in contact with quartzite of the Weisner formation. The ore-bearing material is of two types. That nearest the quartzite is brown clay, such as is commonly formed by the leaching of dolomite of the Rome formation; this clay contains most of the limonite, which occurs in irregular masses. The brown residual clay is overlain by white and yellow weathered metashale, some of which, exposed in the No. 2 cut, is graphitic. Limonite occurs in the metashale as thin, lenticular bodies parallel to the bedding. The metashale contains a little quartzite, which is very thin-bedded in the No. 1 and No. 2 cuts but rather thick-bedded in the No. 3 cut.

The brown residual clay is about 100 feet thick in the No. 1 cut, but not more than 50 feet thick in the No. 2 cut. The thickness of the clay in the No. 3 cut cannot be determined because of the slumping of the walls. Stratigraphic thickness is meant.

The fourth open-cut, known as the Lyle because of recent mining by the Lyle Construction Co., is in clay residual from dolomite but is not near any known contact with quartzite of the Weisner formation. In that cut, jasperoid is unusually abundant in the clay; it occurs in masses as much as 10 feet across.

On the nose of Bartow Mountain, southwest of the No. 1 cut, the Shady formation is known to be present immediately above the quartzite of the Weisner formation. The hematite beds dip east at an angle of 25° and appear to have an aggregate thickness of about 30 feet. These beds were prospected many years ago, and a trial shipment of two cars of highly siliceous ore was made in 1941. The Shady formation extends for at least a short distance west of the prospect and crops out on United States Highway No. 41, where surficial weathering has converted the hematite to ocher. Float fragments of the hematite occur on the slope above the No. 1 cut, and the formation apparently extends northward at least as far as the road between Emerson and Bartow, for ocher and umber occur immediately above the Weisner formation in a bank on the south side of the road.

The Bartow mines and adjacent property have been held as a unit by various interests since 1862, when they were first mined by the Bartow Furnace Co.[63] This company carried on considerable mining until about 1885. The Felton Mining Co. operated the mines for a short time, about 1905, and the property was purchased by the Tennessee Coal, Iron, & Railroad Co. in 1906. The Tennessee Co. operated

[63] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, p. 121, 1900.

the mines for about 4 years, and from about 1917 to 1927 it leased them for operation by the Southern Leasing Co. In 1936, the property was acquired by its present owners, F. D. Smith, F. W. Knight, and W. M. Hardy, who have since done some mining as well as leasing to other operators.

The total output of brown ore from the Bartow mines has not been recorded, but it is probably more than 500,000 tons. The grade of the ore shipped may be inferred from that mined in recent years; ore from the No. 1 cut has carried 43 to 49 percent Fe, as much as 1.8 percent Mn, and 0.2 to 0.49 percent P; that from the No. 3 cut, 48 to 56 percent Fe, as much as 0.5 percent Mn, and about 0.25 percent P.

The Lyle cut was made between 1940 and 1943, and the total output of washed brown ore, produced by five operators, was approximately 87,000 long tons.[64] To produce this amount, about 100,000 cubic yards of ore-bearing clay, estimated to have a weight of 205,000 long tons, was mined. The estimated over-all concentration ratio was 2.4 to 1.

BUFFORD MOUNTAIN

There are two large brown-ore mines on the north slope of Bufford Mountain, on property owned by J. M. Neel. These are shown in plate 1 as mines 30 and 31. Mine 31 is now known as the Bufford Mountain, although both were probably known by this name at the time of operation. Mine 30 is in lot 276, and mine 31 in lot 301. The mines are large open-cuts in the residuum of dolomite and calcareous metashale of the Rome formation. The metashale is conspicuous in mine 31, where it is represented by thin-bedded clay "horses" barren of ore. The residuum from which the ore was mined lies upon the uppermost Weisner rocks.

Mine 30 has an area of about 3.5 acres, and a maximum depth of 60 feet. Quartzite of the Weisner formation underlies the area immediately south and west of the mine, but neither the walls of the cut nor the adjacent surface give any indication of structural details. The rocks that underlie the open-cut have about the same stratigraphic position as those that underlie the adjacent Will Lee manganese mine.

The Bufford Mountain mine (No. 31) has an area of nearly 2 acres, and a maximum depth of 40 feet. The cut is irregular but trends in general northeast parallel to the contact with the Weisner rocks, which crop out on Bufford Mountain to the south. The residual clay contains small masses of specular hematite partly hydrated to brown ore and ocher, indicating the presence of the Shady formation, whose contacts are obliterated, however, by the effects of weathering.

[64] Information from F. D. Smith, part owner

It is doubtful that the hematite is the source of all the brown ore here, for at many other localities the weathering of the hematite in the Shady formation has formed only small amounts of limonite. The geologic feature having greatest genetic significance is a fault that extends from the upper north slope of Bufford mountain northward directly through the mine. (See pl. 1.) The fault has been traced by outcrops of strongly brecciated quartzite, cemented and partly replaced by limonite. The outcrops occur in a broad linear zone about 1,000 feet long. The open-cut extends farthest south at the place where the fault intersects the contact with the ore-bearing residuum, and farther south there are many prospect pits, scattered along the entire course of the structure in the weathered limonitic quartzite. It is likely that pyrite was introduced along the fault zone, replacing dolomite of the Rome formation to a greater extent than the quartzite, and that most of the brown ore was formed by the weathering of this pyrite. Hematite is probably a minor source.

Mine 31 was opened in the 1860's and was operated until 1890.[65] There is no recorded history of mine 30; probably it was operated by the Iron Belt Railroad & Mining Co. about 1900, but the earliest work may date back to the sixties. The writer estimates that the two Bufford Mountain mines may have yielded 200,000 tons of brown ore.

PEACHTREE

The Peachtree brown-ore mine is in lot 148, 22d district, on the property of J. M. Neel. The mine is interesting because of the unusually good evidence regarding the origin of the ore deposit. It consists of two open-cuts, each about 100 feet long, near the summit of a hill at an altitude of nearly 1,300 feet. The northeast cut is a narrow gash driven into the slope from the southeast; it is 60 feet deep at the northwest end. The southwest cut is oriented northeast; it is 25 feet deep although perhaps originally deeper.

Quartzite of the Weisner formation underlies the hill and is exposed in the walls of the cuts. The nearest occurrence of residuum derived from the weathering of carbonate rocks is at the Alexander manganese mine, 1,000 feet to the west. The quartzite is strongly weathered and friable near the surface but is very hard and only slightly leached in the lower part of the deeper cut. The rock is rather thick-bedded, and the bedding planes are sharp and distinct.

The limonite occurs in the quartzite along the foot-wall side of a reverse fault that strikes northeast and dips 45° S.E. The fault is well exposed in both of the open-cuts, as shown in figure 12. The

[65] McCallie, S. W., op. cit., p. 151.

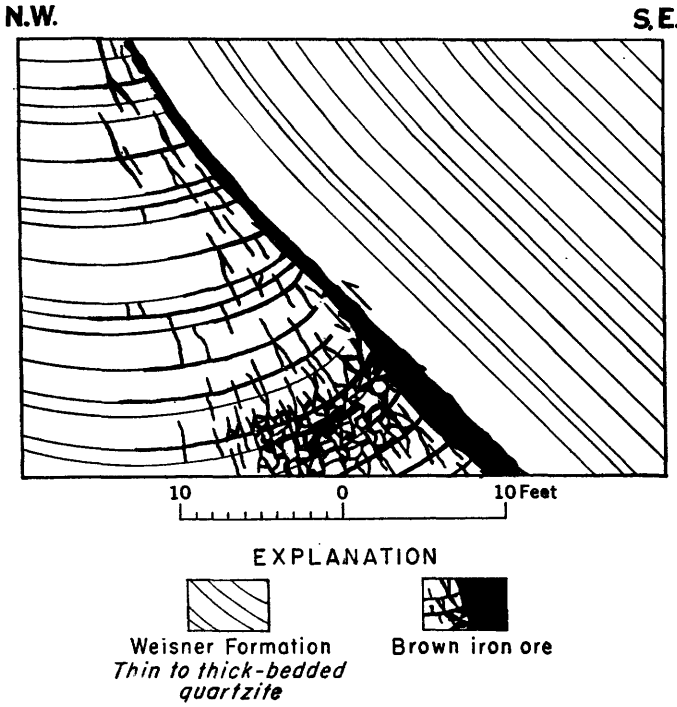


FIGURE 12.—Sketch of reverse fault, in cross section, exposed in Peachtree mine.

beds on the hanging wall side are parallel to the fault plane, but those on the footwall side are flexed and truncated against the fault plane. The flexure, caused by drag during movement along the fault, formed tension joints in the quartzite, and some of the joint blocks were shattered by conflicting movements. Dense limonite occurs between the blocks and fragments of the quartzite, and some of the contacts between them are gradational as if the limonite incompletely replaced the rock. Thus, the limonite gives an exaggerated impression of the width of openings formed by jointing and brecciation.

The limonite-impregnated fault zone has been traced 1.6 miles northeast of the mine by nearly continuous outcrops and float breccia. It forms the south boundary of the area of carbonate rocks of the Rome formation in whose residuum the Black Bank iron and manganese deposits occur. (See pl. 1.) Fresh quartzite, found adjacent to the fault zone 0.7 mile northeast of the Peachtree mine, contains pyrite. It is likely that all the limonite was formed by the weathering of pyrite deposited hydrothermally in the fault zone.

The Peachtree mine was opened before the Civil War, and was abandoned before 1900.[66] According to local information, it was in operation in the eighties. There is no record of the output of ore. It is said that the deposit contained a "streak" of black highly manganiferous limonite, but this cannot be verified as there is no visible indication of manganese in the ore now exposed.

[66] McCallie, S. W., op. cit., p. 169.

SUGAR HILL GROUP

The Sugar Hill group of brown-ore mines consists of six open-cuts in lots 257, 258, and 283, in the 22d district. The lots are owned by J. M. Neel. The mines are on and adjacent to the east and south slopes of Sugar Hill, an east spur of Little Pine Log Mountain.

Quartzite and metashale of the Weisner formation are exposed on the higher part of Sugar Hill, and the weathered residuum of dolomite and calcareous metashale of the Rome formation overlies the Weisner rocks on the lower slopes. Diverse attitudes of the Weisner rocks reflect intricate folding, as shown on the geologic map. (See pl. 1.) The brown ore occurs in the residuum of the Rome rocks, and the uppermost Weisner rocks are the footwall of the ore bodies.

The Sugar Hill-Kinsey cut is in lot 258 and is nearly half a mile long. Its area, which is about 16 acres, is second only to that of the Paga No. 1 barite mine, and the maximum depth is 75 feet. The mine was started as two cuts, which were enlarged by mining and finally merged to form the present large and irregular opening. The original south cut was known as the Sugar Hill mine, and the original north cut as the Kinsey mine.

The Cripple Creek mine also is in lot 258, immediately southwest of the Sugar Hill-Kinsey mine. It is a relatively small open-cut, about 25 feet deep, in ore-bearing residuum that occurs in a narrow syncline plunging south.

The Pine Hill and Bluff mines are in lot 257, about one-half mile west of the Sugar Hill-Kinsey. The Pine Hill cut has an area of about 3.5 acres; water is ponded permanently in the cut, and the original depth is not known. It is the second largest mine of the group. Quartzite of the Weisner formation forms the footwall of the deposit and crops out along the northwest side of the cut. The quartzite trends southwest where it also forms the footwall of two smaller cuts, known as the Bluff mine, in the same lot. The Bluff cuts are about 30 feet deep.

The sixth mine is unnamed. It is in lot 283, 700 feet north of the Sugar Hill-Kinsey mine and adjacent to the uppermost Weisner rocks. The area of the cut is only a little more than half an acre, but its depth is about 65 feet. It appears to have been the last mine worked, for the railroad that originally extended through the Sugar Hill-Kinsey cut to the Pine Hill cut was rerouted for the operation of the mine in lot 283.

Except at the mine in lot 283, the material from which all the brown ore was mined consists of yellow to brown clays containing much jasperoid. This residuum is similar to that formed elsewhere in the district by the weathering of carbonate rocks of the Rome formation but contains a larger proportion of weathered metashale. At the mine in lot 283, the ore-bearing material is largely metashale that is unevenly graphitic; dolomite residuum occurs only in the northwest wall and contains pyritic jasperoid. These differences illustrate the lack of lithologic uniformity of the lower Rome rocks, for all the mines are in material of the same stratigraphic position.

The dumps consist largely of jasperoid, most of which is strongly weathered. Some of the less weathered jasperoid contains pyrite. Plate 14*A* shows a specimen collected in the east part of the Sugar Hill-Kinsey cut. The specimen is mostly fine-grained pyrite containing small masses of milky vein quartz and jasperoid, and is interpreted as follows: dolomite was veined by milky quartz, and was later ruptured, giving access to solutions that deposited pyrite, which replaced most of the dolomite; small residual bodies of the dolomite were subsequently replaced by quartz when jasperoid was formed in the carbonate rocks throughout the district. The uppermost beds of Weisner quartzite, in the west wall of the same cut, were blasted in the course of mining. The quartzite waste is fresh and contains pyrite in abundance; some of the rock is more than half pyrite.

A mass of allophane 8 inches thick was found on one of the Sugar Hill mine dumps, but the mineral was not observed in place. The mass contains veinlets and crusts of a greenish-blue supergene copper silicate whose presence indicates that the primary pyrite deposits contain a small amount of one or more copper sulfides that are known elsewhere in the vicinity. (See pp. 92.)

McCallie[67] and Catlett[68] have described iron carbonate at the Sugar Hill-Kinsey mine, and an analysis of the mineral was given by McCallie. The writer has not found any iron carbonate at the mine, but gives full credence to these reports and believes that the brown ore was formed in part by the weathering of the iron carbonate. It is believed that pyrite is the principal source, however, for it is unlikely that the mineral would be so common in the mine waste, in spite of the deep and strong effects of oxidation, if it had not been present in very large amounts before weathering.

Two fairly well defined faults, which are shown on the geologic map (pl. 1) probably served as the principal conduits for hydrothermal solutions that deposited the pyrite and carbonate. The solutions apparently spread laterally through the carbonate rocks, which occur between quartzite of the Weisner formation and metashale of the Rome formation, along joints and fissures formed by the intricate folding of the beds.

The Sugar Hill deposits were mined on a very small scale before the Civil War, and there was no further mining until large-scale operations were started in June 1898.[69] This work was carried on by L. S. Munford and J. W. Akin, as the Iron Belt Railroad & Mining Co. The deposits were mined intensively by this company for about 4 years. All mining was done by hand and as many as 200 men were employed, producing an average of about fifty 40-ton cars of washed ore per day.[70] The mining year averaged about 250 days, and the indicated output during the four-year period, therefore, is about 2,000,000 tons; it is locally reported that the output was 3,000,000 tons.

The property was acquired about 1902[71] by Joel Hurt, Sr., who continued operations until 1906 on a considerably smaller scale. The output from this work is unknown, but it may have amounted to 500,000 tons.

The total output of brown ore from the Sugar Hill group of mines, therefore, is estimated to be about 2,500,000 tons, or one-half that of the entire district and one-fourth that of the State.

VINEYARD MOUNTAIN GROUP

There is a group of seven brown-iron mines within a distance of half a mile along the ridge that extends southward from Vineyard Mountain. The open-cuts have a combined area of nearly 2.5 acres. The northernmost cut is on the south slope of the mountain. (See pl. 1.) The cuts are in land lots 575, 578, and 579, in the 21st district, on the property of W. R. Hale.

The deposits occur in rocks of the Weisner formation, and their geologic environment is similar to that of most other deposits in this formation, notably the Wildcat Hollow group. The Weisner rocks strike north and dip east; they are much weathered, and they consist mainly of fissile to massive quartzite interbedded with white to light-brown metashale and a little metasiltstone. The brown ore occurs in lenticular bodies oriented parallel to the bedding of the rocks, as well as in irregular masses in brown clay similar to that derived from the weathering of carbonate rocks of the Rome formation. The metashale and quartzite adjacent to the ore bodies are barren of limonite.

The series of Weisner rocks in which the deposits occur is transected by Etowah River at the Allatoona dam site, 0.6 mile north of the mines. The

[67] McCallie, S. W., op. cit., pp. 19, 162-163.

[68] Catlett, Charles, Discussion, Am. Inst. Min. Eng. Bi-monthly Bull. 24, pp. 1179-1183, 1908.

[69] McCallie, S. W., op. cit., p. 156.

[70] McCallie, S. W., op. cit., 156-166. Also oral information from R. S. Munford.

[71] Hayes, C. W. and Eckel, E. C., Iron ores of the Cartersville district, Georgia, in Contributions to economic geology, 1902: U. S. Geol. Survey Bull. 213, p. 241, 1903.

series there has been thoroughly explored by core drilling by the Corps of Army Engineers. The fresh rocks from the drill holes are mostly metashale, quartzite, and metasiltstone, but numerous beds of crystalline magnesian limestone also were encountered. (See p. 9.) It is apparent, therefore, that the weathered brown clays and metashales exposed in the mines were derived from the weathering of similar massive to micaceous limestone.

The core drilling at the dam site did not reveal any primary mineral, except a little pyrite, whose weathering would form limonite. The sharply defined limits of the brown-ore bodies, and their structural conformity with the enclosing rocks, indicate that the limonite was formed in place by the weathering of lenticular bodies of a primary iron-rich mineral. The mineral was probably pyrite, which has been found in fresher rocks taken from other brown-ore mines in both the Weisner and Rome formations. The presence of limestone as a likely host rock for sulfide replacement is also suggestive of such an origin.

The Vineyard Mountain deposits were first mined on a small scale before the Civil War, but there was no mining from that time until the late nineties, when the Etowah Iron Co. began operations.[72] This company was apparently reorganized as the Etowah Development Co. about 1907, and the property was acquired shortly afterward by the LaFollette Coal & Iron Co., which operated the mines until 1914; these companies produced 74,125 tons of brown ore from 1907 to 1914.[73] The mines have been abandoned since 1914.

There is no record of production before 1907. As the earlier mining was of smaller scale, however, it is likely that the total output from the Vineyard Mountain group did not exceed 100,000 tons.

OCHER MINES

CHEROKEE

The Cherokee ocher mine, owned by the Cherokee Ochre Co., is in lot 406, 4th district, 200 feet east of the newer Cherokee barite mine. The relation of the mines is shown in figure 13.

The ocher mine is an open-cut with an area of about 0.8 acre and a maximum depth of 70 feet. The cut is oriented N.15°E. The east and west walls expose quartzite and metashale of the Weisner formation. The rocks on the east side of the cut are gently folded, and the fold axes trend nearly east. (See fig. 13.) Those on the west side dip to the west and are overlain in the adjacent Cherokee barite mine by the residuum of Shady and Rome rocks. The ocher mine exposes weathered, thin-bedded, ocherous clay like that normally formed by the weathering of the thin-bedded hematite of the Shady formation. The bedding of the clay strikes north and dips 25° W.

The body of ocherous clay occurs between the Weisner rocks and is abnormally in contact with them. The abnormal relation is reflected by the divergent attitudes of the beds and is clearly exposed in the upper south wall of the cut, where the Weisner rocks in the east wall are truncated against clay residual from dolomite. The plane of truncation is approximately vertical, and the bedding of the Weisner rocks is horizontal.

Bedded ocherous clay is unknown in the weathered Weisner rocks of the district, but it is the common product of the weathering of hematite of the Shady formation, which overlies the Weisner rocks. The Shady is normally overlain by dolomite of the Rome formation, which weathers to clay like that in the upper south wall of the cut. It is apparent that the plane of truncation in the south wall is a fault plane and that the Weisner rocks in the west wall must be separated from the ocherous clay by a similar and parallel fault, although the slumping of the wall has obscured the actual relation.

The body of ocherous clay, therefore, is interpreted as a graben about 100 feet wide that was dropped along two parallel faults. The bedded ocherous clay in the graben is weathered hematite of the Shady formation, probably underlain at shallow depth by Weisner rocks, and the overlying unbedded clay is residual from the lower part of the dolomite of the Rome formation. The graben has a length of at least 700 feet south of the mine, where the narrow body of residual clay contains barite and has been prospected at close intervals.

Watson's report[74] indicates that the ocher was mined at first from shallow underground workings, which were later developed into the present open-cut. The mine was operated by the Cherokee Ochre & Barytes Co. from 1894 to 1904, and by the Cherokee Ochre Co. from 1904 to 1941; since then it has been idle. The output of refined ocher from 1894 to 1912 was about 20,000 long tons, and that from 1913 to 1941 was 31,242 long tons.[75] It is recorded in long rather than short tons because the entire output of the mine has been shipped abroad.

KNIGHT

The Knight mine is in lot 404, 4th district. Its main opening is an open-cut 600 feet long, 175 feet in maximum width, and 50 feet in maximum depth. Mining is done by tunnels and shafts, and the large

[72] McCallie, S. W., op. cit., pp. 130-131.

[73] Hazeltine, R. H., Iron ore deposits of Georgia: Georgia Geol. Survey Bull. 41, p. 14, 1924.

[74] Watson, T. L., A preliminary report on the ocher deposits of Georgia: Georgia Geol. Survey Bull. 13, p. 41, 1906.

[75] Dates and amounts furnished by Miss Nell Posey, agent of the Cherokee Ochre Co.

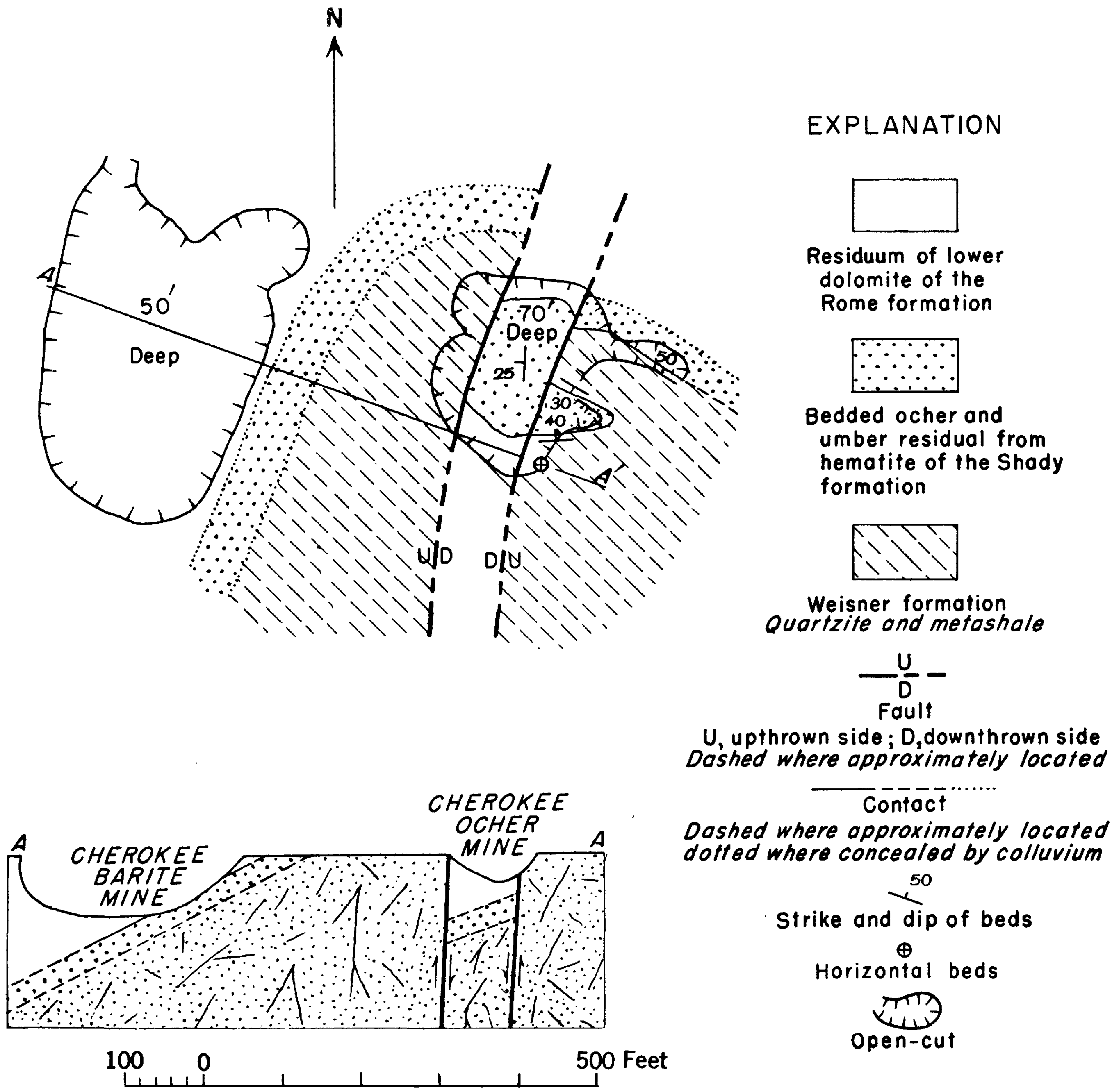


FIGURE 13.—Sketch map and section showing relation and geology of Cherokee ocher and barite mines.

size of the open-cut is the result of collapse of underground workings together with large-scale stripping by power shovel.

The open-cut and the underground workings are in a stratigraphic zone of residual clays that conformably overlie thick-bedded quartzite of the Weisner formation. The quartzite forms the east wall of the cut, where it strikes N. 30° W. and dips about 45° SW. The clay zone is 50 feet thick in the northern and central parts of the cut but is only 15 feet thick in the southern part, where the strike of the quartzite changes abruptly to N. 75° E. Immediately north of the flexure there is a fault striking about N. 45° E.; the horizontal displacement on this fault is about 10 feet, and the movement appears to have been horizontal.

The residual clay is overlain by white to light-gray weathered metashale, which also dips west and is exposed in the west wall of the cut. The metashale occurs in a narrow synclinal body, because 200 feet west of the cut its beds dip east, and the underlying residual clay there contains barite.

The clay nearest the quartzite is thin-bedded, ocherous, and umberous and is the leached residuum of hematite of the Shady formation. The clay nearest the overlying metashale is brown and unbedded and is the residuum of dolomite of the Rome formation. The leaching of the rocks has evidently caused little reduction in thickness, for the bedded structure of the ferruginous clays and that of the overlying metashale is undistorted. The thin body of clay residual from dolomite is good evidence of the eastward thinning of the carbonate rocks in the lower part of the Rome formation. (See pp. 15-16.) The residual clays and the metashale are overlain by colluvium and can be distinguished only in the open-cut. This exemplifies the difficulty of differentiating the lower beds of the Rome formation in much of the western part of the district.

The color of the clay exposed in the mine ranges from bright yellow to dark brown. The beds range from less than 1 inch to about 6 inches in thickness, and the bedding planes are sharply defined. A fairly uniform color characterizes each bed for a distance of 10 feet or more in the plane of the bedding, but commonly the color varies sharply between adjacent beds. At least a quarter of the material in the walls of most of the tunnels is of bright orange yellow.

The mine has been operated intermittently since 1927 by J. M. Knight for the New Riverside Ochre Co. The output is unknown, because it has been combined with that from other ocher workings. Information furnished by the company indicates, however, that the total is at least 40,000 short tons of refined ocher. The average recovery is 1 ton of refined ocher from 2 tons of raw ocher.

SPECULAR-HEMATITE MINES

RED NO. 1

The Red No. 1 hematite mine is in lot 300, 5th district, on the property of J. M. Neel. It is an open-cut, oriented N. 65° E., 600 feet long, 200 feet in maximum width, and having a depth of at least 40 feet near the southeast wall. The maximum original depth is unknown, because water is ponded in the bottom of the cut.

Specular hematite and brown ore were mined together from the cut,[76] but their relative proportions are not recorded, and little of either ore is now exposed. Hematite crops out in the southwest part of the higher wall and occurs sparingly as float on the adjacent surface. The dumps contain pyritic jasperoid, and it is likely that the weathering of both hematite and pyrite contributed jointly to the formation of the limonite. As the hematite is not so rapidly weathered as the pyrite, the ore mined contained much residual hematite.

The geology of the mine is obscure. The cut is located on the northwest slope of a low hill and is parallel to its crest. The hill is underlain by deeply weathered quartzite and metashale of the Weisner formation, which are exposed in the adjacent northern cut of the Bufford manganese mine. As specular hematite occurs only in the Shady formation, immediately above the Weisner, it would appear that the crest of the hill is the axis of an anticlinal fold, and that the mine is in the northwest limb of the fold. The bedding of the deeply weathered rocks in the southeast wall of the cut appears to dip steeply southeast, which indicates that the fold is overturned toward the northwest.

The jasperoid in the dumps evidently occurred in residual clay that was stripped along the northwest side of the ore-bearing zone, and hence the Shady formation is probably overlain by dolomite of the Rome formation. That is the common stratigraphic sequence, and is also the sequence at the Red No. 2 mine, half a mile to the northeast. The valley of Big Spring Creek, immediately northwest of the open-cut, is probably underlain by clay residual from the dolomite, but its floor is covered with log-washer tailings accumulated during many years of washing manganese ores.

The Red No. 1 mine was opened during the seventies by R. H. Renfroe, and was operated intermittently until the late nineties. The later work was done by George F. Hurt concurrently with the operation of the Red No. 2 mine. According to local information, the output of hematite and brown ore was large, but the amount and proportions are unknown. The output of hematite alone is said to have been smaller than that from the Red No. 2 mine.

RED NO. 2

The Red No. 2 mine is in lots 299, 313, and 314, 5th district, on the property of J. M. Neel. The location and geologic relations of the mine are shown in plate 18.

The mine consists of two open-cuts, 300 feet and 1,200 feet, respectively, southeast of the Little Aubrey manganese mine. The cuts were made in the hematite beds of the Shady formation, which cropped out parallel to the uppermost beds of the Weisner formation. These beds reflect an anticlinal structure, and the fold plunges northeast. The open-cuts occur on opposite sides of the crest of the fold.

The east cut is 400 feet long; the maximum width is 100 feet, and the maximum depth 30 feet, but these dimensions have been modified by erosion, and the original dimensions are unknown. The uppermost beds of quartzite of the Weisner formation dip eastward beneath the cut at an angle of 25°.

The west cut is 750 feet long, and the maximum width is 125 feet. The width and depth have been greatly modified by the slumping of residual clay from the northwest wall, but the approximate original depth has been furnished by one of the mine

[76] McCallie, S. W., A preliminary report on a part of the iron ores of Georgia: Georgia Geol. Survey Bull. 10-A, p. 152, 1900.

foreman. According to this information, the west cut was a stope inclined northwest down the dip of the hematite. It had an average inclined depth of 40 feet except at the southwest end where the depth was about 100 feet; water is now ponded in the originally deeper part.

At the northeast end of the deeper part of the cut, there is an offset in the footwall of quartzite of the Weisner formation, and the quartzite here is highly fractured. The offset is reflected in the abrupt bend of the cut and is the result of faulting of relatively small displacement. The fault appears to trend toward the northeast end of the Little Aubrey open-cut.

The mine was opened by R. H. Renfroe about 1880, but it was operated principally by George F. Hurt during the nineties; since that time it has been idle. On the basis of local information, the output of hematite ore appears to have been at least 25,000 long tons. The maximum reported width of minable ore was 10 to 12 feet, in the southwest part of the west cut.

ROAN

The Roan hematite mine is in lot 616, 4th district, 2.5 miles southeast of Cartersville. It comprises the eastern third of a linear group of workings that extend westward across the extreme northwest corner of lot 681, across lot 680, and into lot 679. The name Roan was applied only to the workings on lot 616, but the entire group is in a continuous outcrop of hematite beds of the Shady formation, and operations were carried on at about the same time. Lot 616 is the property of W. R. Hale; lots 679, 680, and 681 are the property of the Virginia Iron Coal & Coke Co.

The topography and surface geology of the mine are shown in figure 14. The hematite occurs in bedded, residual masses enclosed in similarly bedded ocherous and umberous clays. The bedding is transitional from the hematite into the clays, which have clearly been formed by the hydration of the primary ore beds. Small and irregular parts of the clays have the bright color required of commercial raw ocher. Random thick beds of the clays contain little ferric hydroxide and are like the clays residual from the overlying dolomite of the Rome formation. They contain masses of jasperoid, and both the jasperoid and the residual hematite in places contain the Shady fossils that date the formation. The dolomite residuum indicates that dolomite is interbedded with the hematite below the zone of weathering, but its relative abundance cannot be determined from surface exposures.

The weathered Shady formation is conformably in contact with quartzite and metashale of the Weisner formation, and the contact trends about N. 55° E. The quartzite dips vertically at the surface except in the western part of the mine where it dips steeply northward. The base of the Shady formation is well exposed against the uppermost bed of the quartzite, which is relatively resistant to weathering. The top is not well exposed, but the maximum thickness of the formation appears to be 30 feet. Exposures do not show whether the thickness is uniform.

The residual ore ranges from nearly pure hematite to a mixture of fine-grained quartz and hematite in uneven proportions. The hematite is platy to thickly tabular and is oriented parallel to the bedding. Some of the ore is weakly to rather strongly magnetic, but a polished section of such material from another property shows no magnetite. Published analyses[77] of the ore show a range of 38 to 66 percent Fe, and a total of less than 1 percent of manganese, phosphorus, and sulfur. The dumps contain about 7,000 cubic yards of highly quartzose, hematite-bearing rock rejected in the production of hand-cobbed concentrates.

McCallie[78] reported that the Roan Iron Co. produced about four cars of the ore per day for 8 months during 1877, but the extent of the workings indicates an operation of perhaps several years' duration. As mining was selective, it seems possible that the total output may have amounted to 30,000 tons or more.

The workings, all badly caved, consist of many small open-cuts and pits, 10 or more tunnels, and at least 2 vertical or inclined shafts. The greater part of the mining was done in two deep ravines that cut nearly at right angles across the strike of the formation, as shown on the map. The shafts were sunk in the ravines, and there is a local report that they reached a depth of 200 feet. Probably four tunnels were driven along the strike of the ore beds from the two ravines. At least six tunnels were driven into the hill slope, directed to intersect the ore beds at various depths down to 130 feet. Willis[79] reports that one of these, 200 feet long, was connected with a drift 400 feet long in the ore beds. He states that the workings were abandoned in 1878 and quickly became inaccessible.

MISCELLANEOUS MINERAL DEPOSITS

BARITE CRYSTALS

Deposits of water-clear, tabular barite crystals, of the type described on pages 47, 50 and shown in

[77] McCallie, S. W., op. cit., pp. 125, 135. Watson, T. L., A preliminary report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 14, p. 66, 1908. Willis, Bailey, Notes on the samples of iron ore collected in Georgia: U. S. Geol. Survey 10th Census, vol. 15, p. 374, 1886.

[78] McCallie, S. W., op. cit., p. 124.

[79] Willis, Bailey, op. cit., pp. 373-374.

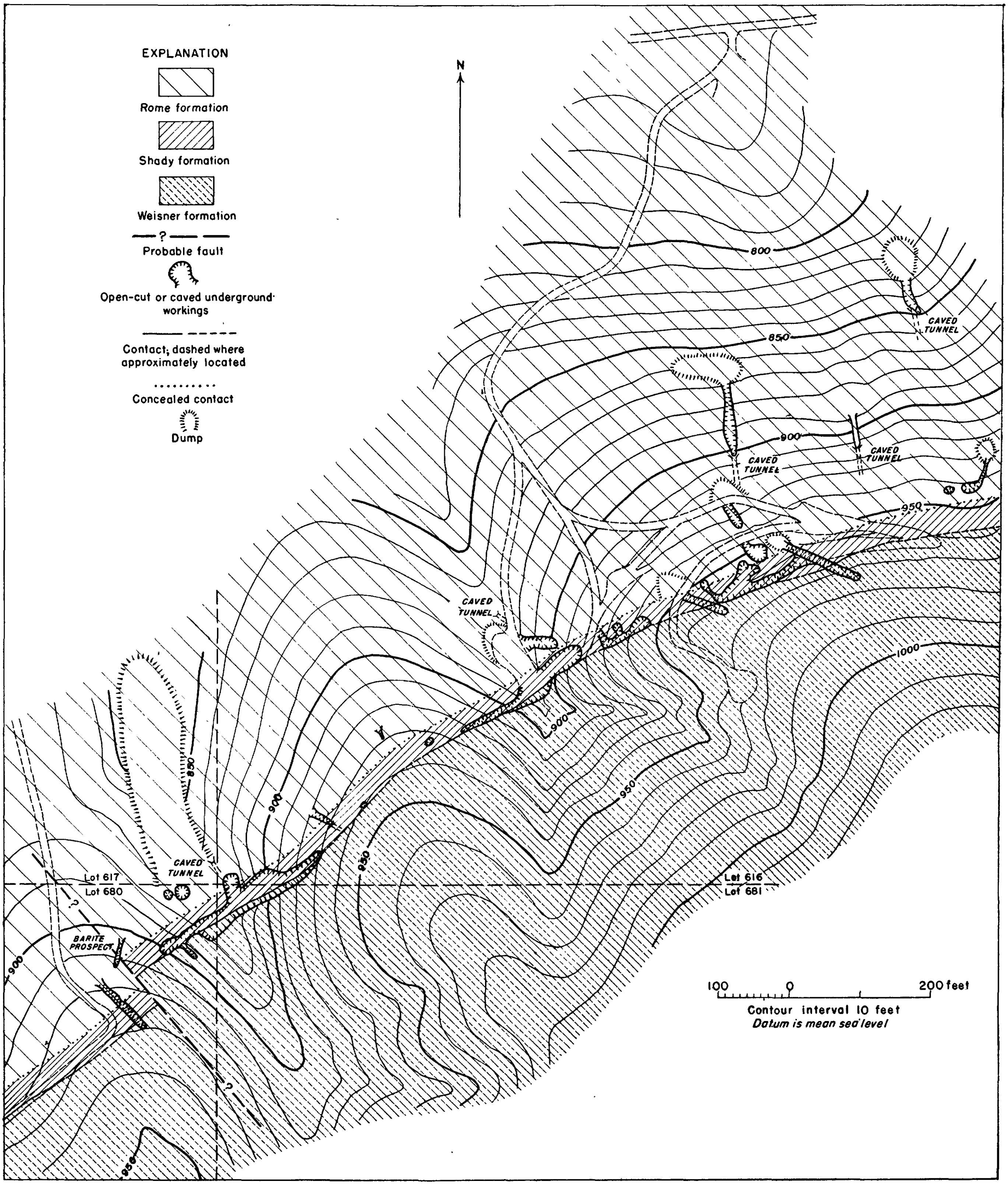


FIGURE 14.—Map of Roan hematite mine and vicinity.

plate 14*E, F*, occur along the north side of Pumpkinvine Creek, 1.5 miles southwest of Emerson. Several prospects have been opened, but the production of concentrates has been attempted at only one. This is the Puckett prospect, locality number 1, immediately northwest of the Chulafinnee mine.

The coarsely crystalline barite occurs in individual crystals and irregular and veinlike aggregates enclosed in large residual boulders of jasperoid, and in adjacent residual clay where it has been freed by the weathering and disintegration of some of the jasperoid. Limonite stains are common on the crystals that occur in the clay and on those in deeply weathered jasperoid. Crystals that are weathered out of the jasperoid are commonly coated by minute terminated quartz crystals. (See pl. 14*E, F*.) These appear to have been deposited by ground water, for the unweathered jasperoid contains no terminated quartz crystals.

The Puckett deposit has been tested by a tunnel driven about 50 feet into the residual clay and jasperoid. Fifty tons of washed and jigged barite concentrates, reportedly high in silica and iron, was produced in 1941 from hand-selected ore taken from the tunnel.

As only a small part of the barite of this type has been freed by the weathering of the jasperoid, the production of any considerable tonnage of concentrates would necessitate the crushing of barite and jasperoid together and a separation by means other than the conventional log washer and Harz jigs. O'Meara and Coe[80] have shown that silica can be satisfactorily eliminated by hydraulic classification and tabling from barite ore ground to minus 28 mesh; and both silica and iron by flotation from ore ground to minus 65 mesh.

Either method of beneficiation would probably be efficient, as the iron oxide associated with the crystalline barite occurs in objectionable amounts only in the most weathered ore. Economically, crushing the barite-bearing jasperoid would probably be the chief deterrent to mining.

GRAPHITE

The metashales of the Cambrian formations in places contain unevenly disseminated, finely divided graphite, but only those of the Rome formation have attracted economic interest. The graphitic rock, which is weathered and relatively soft, has been mined from two open-cuts. One of these cuts, whose area is about 20,000 square feet, is a half mile south of the Cemetery Hill mine at locality number 2. Mining was being carried on there in 1907 by the Cherokee Chemical Co., and the rock was ground for use as a filler in fertilizer.[81] Shortly after 1914 it was used by the Atlanta Vitrified Brick Co. in the manufacture of vitrified building and paving brick.[82] The other cut is immediately northeast of Bartow at locality number 3. It has an area of about 65,000 square feet and was made about 1907 by the American Chemical Mining Co. who ground the graphitic rock for use as a filler in fertilizer.[83] There is no record of any attempt, in either operation, to concentrate the finely disseminated graphite.

Small folds occur in the metashale at the cut south of the Cemetery Hill mine, and the rock is unevenly pyritic. Two of the common products formed from the weathering of pyrite are ferric sulfate and ferric hydroxide, which result from the oxidation of ferrous sulfate. These products occur in and near the open-cut as thick masses of yellow and orange ferric sulfate[84] as much as a foot across on the wall of the cut, and a coating of brown ferric hydroxide on all vegetation submerged in water that drains from the dumps.

GOLD

Gold-bearing quartz veins and small placer deposits in the southeastern part of the district were mined during the nineteenth century, but very little gold mining has been carried on since about 1880. All deposits known to the writer occur in and adjacent to the areas underlain by amphibolite, but a small placer deposit is locally reported one mile northeast of Signal Mountain, in an area underlain by porphyroblastic gneiss. This unique deposit could not be found by the writer.

There is little record of the extent of the workings and no record of the output. All the underground workings are inaccessible. The veins were mined to or below the level of ground water, and outcrops of the country rocks give no geologic basis for inferring the extent or attitude of the veins at greater depth. The two largest mines are the Allatoona and the Glade. Their respective locations are shown by the locality numbers 4 and 5 in plate 1, and the published information concerning them is summarized below.

Allatoona mine (No. 4)—There have been at least three periods of operation at the Allatoona, or Tudor, mine, which is 0.6 mile east of Allatoona. The most extensive work was carried on from 1835 to 1840; during that period the oxidized ore, which occurred in a vein or veins 1 to 4 feet thick, was mined to a

80 O'Meara, R. G., and Coe, G. D., Concentration of Southern barite ores: U. S. Bur. Mines Rept. Inv. 3376, pp. 3-6 10-12, 1938.

81 Hayes, C. W. and Phalen, W. C., Graphite deposits near Cartersville, Georgia, in Contributions to economic geology, 1907: U. S. Geol. Survey Bull. 340, pp. 464-465, 1908.

82 Smith, R. W., Shales and brick clays of Georgia: Georgia Geol. Survey Bull. 45, pp. 274-276, 1931.

83 Hayes, C. W. and Phalen, W. C., op. cit., pp. 463-465.

84 Qualitative analyses by Michael Fleischer.

depth of 40 feet for a distance of 200 yards, and adjacent placer deposits were washed.[85]

Anderson[86] reports that a shaft sunk to a depth of 50 feet in 1878 was reopened in 1932, when it was found to be connected, by a drift 75 feet long, with underground workings made in 1840. The old workings were confined to a zone of intense fracturing and oxidation pitching 30° NE. They followed a quartz vein 5 feet thick, but this vein was barren except for a 1-foot streak on the footwall side, where values were as high as $12.40 per ton. The shaft was deepened to 100 feet, and a drift was run northeastward along the vein. At a distance of 200 feet from the shaft the vein entered the oxidized zone pitching from the 50-foot level. The drift was driven 30 feet into the oxidized zone, but was abandoned when it was found that the richest samples assayed only $1.80 a ton. Anderson's report contains photomicrographs that show the occurrence of gold, galena, and bornite with chalcopyrite in the vein quartz.

Glade mine (No. 5)—At the Glade mine 2.3 miles east of Allatoona, there are two shafts, each in a different quartz vein, neither of which appears to have been reopened since the mine was abandoned, not later than 1909.[87] One of the shafts, the Eastport, was sunk to a depth of 80 feet on a quartz vein 2 or 3 feet thick assaying up to $10 per ton; the other shaft, the Adams or Francisco, was sunk 50 feet on a large quartz vein whose thickness and grade are not recorded.[88]

PICROLITE

In land lot 372, 21st district, 0.4 mile northwest of Macedonia School, is a deposit of picrolite (a variety of serpentine) indicated by the locality number 6 in plate 1. A shallow pit 12 feet in diameter was dug in the deposit many years ago, and a shaft about 25 feet deep was sunk beside the pit in 1937. No rock is now exposed in the pit which is filled with debris; the shaft encountered only rock consisting mostly of picrolite.

The body of this rock is enclosed in porphyroblastic gneiss. Its contacts are not exposed, and its size and attitude are not fully known. The body is probably at least 10 feet thick, and appears to strike N. 30° W., parallel to the local strike of the gneiss; no estimate of the length can be made.

The picrolite is bluish-green, is asbestiform, and has a mean index of refraction of 1.57. It is harsh and brittle and probably is not adaptable to commercial uses. The picrolite is in tabular veins, mostly less than 1 inch thick, with the fibers oriented parallel to one another and oblique or transverse to the walls. It also makes up most of the rock between the veins, but the crystals in the rock are short and diversely oriented. Fine-grained chlorite occurs irregularly in dense aggregates in the rock.

The deposit is approximately in strike with the lenticular body of carbonate rocks of the Rome formation that includes the Iron Hill brown-ore and barite deposits, and the picrolite may have been formed by the alteration of a lenticular body of carbonate rock during the emplacement of the enclosing gneiss.

COPPER

In the extreme northern part of the district, a vein of quartz and dolomite containing a little chalcopyrite and enargite (see pl. 15*B*) has been prospected on the south bank of Sugar Hill Creek, 0.4 mile northeast of Fairview Church. The location is shown by the locality number 7 in plate 1. There is no published account of the exploration, but some prospecting for copper is said to have been done in the district about 1855,[89] and the prospect probably was opened at about that time.

A shaft about 25 feet deep was sunk on the vein, but it is now so filled with debris that the vein is exposed only within a few feet of the surface. The vein is quite irregular, but it has an average thickness of not more than a foot and appears to be vertical. It is enclosed in dark-gray crystalline dolomite containing a few beds of crystalline limestone that strike N. 20° E. and dip 55° NW. The strike of the vein appears to be parallel to that of the dolomite. Crusts of malachite, formed by the weathering of the sulfides, occur in joints in the vein and in the adjacent dolomite. The vein contains so little of the chalcopyrite and enargite that it probably has no economic importance.

Another minor copper deposit is exposed in the east bank of United States Highway No. 411 on the north side of the Pine Log Creek bridge. It is in dark-blue dolomite, which is considerably fractured and unevenly silicified but almost unweathered. The fractures contain vein quartz and a little chalcopyrite and tennantite. Azurite and malachite have been formed by weathering along a few of the fractures nearest the surface. There is no other exposure of dolomite containing ore minerals in the vicinity, and the exposure described is so small that the trend of the fracture zone cannot be determined. This deposit, like the other one, appears to be economically unimportant.

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[85] Yeates, W. S., McCallie, S. W., and King, F. P., A preliminary report on a part of the gold deposits of Georgia: Georgia Geol. Survey Bull. 4-A, pp. 218-220, 1896.

[86] Anderson, C. S., Gold mining in Georgia: Am. Inst., Min. Met. Engrs. Trans., vol. 109, pp. 61-68, 1934.

[87] Jones, S. P., Gold deposits of Georgia: Georgia Geol. Survey Bull. 19, p. 146, 1909.

[88] Yeates, W. S., McCallie, S. W., and King, F. P., op. cit., pp. 220-221.

[89] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, p. 148, 1919.

FUTURE OUTLOOK FOR MINING

PRELIMINARY STATEMENT

Future mining in the Cartersville district may involve the primary deposits of specular hematite and pyrite that occur in bedrock below the zone of weathering, as well as the secondary mineral deposits that occur in residuum in the zone of weathering. The primary deposits are deeply covered by the residuum, and the secondary deposits are covered by colluvium and are exposed only where the colluvium has been removed by erosion or mining. Owing to these conditions, the limits and grade of the mineral deposits cannot be determined even approximately without systematic exploration. Since little systematic exploration has been undertaken, it is impossible to estimate ore reserves on individual properties, or in the district as a whole. It is possible only to form limited conclusions as to whether reserves of the different ores are in general appreciable, and these conclusions must necessarily be based on the character and geologic setting of the deposits rather than on exploratory data.

Barite and manganese may be considered together, for the residual ores of both occur and are mined and treated under generally similar conditions, and there is no present indication that the primary sources of these ores will be of commercial interest in the near future. Brown iron and pyrite, likewise, may be considered together, for any future prospecting of pyrite deposits will be confined to the environs of the brown-ore deposits. Ocher, umber, and specular hematite, again, may be considered together, for both the ocher and the umber deposits have been formed by the weathering of the hematite.

BARITE AND MANGANESE

There are few unprospected surface indications of residual barite and manganese deposits, but surface indications of such deposits were never large or numerous. Those that were noticed early were in areas where the colluvial overburden was thin and float ore was exposed by erosion. Subsequent mining in those areas has developed the present large open-cuts, but it is evident in the walls of the cuts that mining was expanded far beyond the limited areas in which the float was visible originally. It is further evident, in many of the cuts, that mining would have been expanded even more were it not for the increasing depth of overburden with increasing distance from the sites of discovery. The full extent of a body of ore-bearing clays bears no predictable relation to that of the area containing the surface indications that lead to the discovery of such a body. Nor is the present depth of mining in a deposit fully indicative of the vertical extent of the ore, for in many places mining has reached the level of ground water without revealing any change in the character of the clay or of the ore minerals that it contains.

It is evident from these facts that the ore-bearing clays are far from exhausted; but those that remain are in general less accessible than those previously mined, and their recovery will generally involve a gradual increase in mining costs. The future mining of barite and manganese may depend principally on a gradual increase in demand and hence in the prices of concentrates, but the increasing costs of stripping and deeper mining also may be met in part by some revision of operating methods.

Carefully planned exploration, which has been so lacking in the past, is essential, and its value has been proved in several instances. The Paga Mining Co. has recently demonstrated the efficiency of a portable rotary drill in the development of barite reserves. Drilling at the Winterbottom and Slabhouse mines has shown that the deposits are much larger than was known from previous mining without exploratory guidance: ore has been proved to a depth of 100 feet or more in areas adjacent to both mines. The churn drill is the most effective tool that has been used hitherto in prospecting manganese deposits, but the cuttings do not show the true physical character of the ore, and mill samples must be obtained from shafts.

Deeper mining will require the stripping of overburden in amounts that have been prohibitive in the past. Contract stripping with modern equipment in 1944 costs about 25 cents a cubic yard, but stripping by the operators is said to cost less. It may be feasible to do hydraulic stripping where topography and water supply are favorable. Mining has been done by hydraulic and power-shovel methods. Shovel mining is obviously the more selective, and the importance of this feature may increase in proportion to the cost of deeper mining.

The few available figures on the grade of tailings deposits (pp. 59-60) indicate that there is much room for improvement in methods of concentration. The installation of tables in two of the barite mills in comparatively recent years started a trend toward improvement in recovery. In 1944, Thompson-Weinman & Co. were completing a five-cell flotation plant to beneficiate the table products and higher-grade tailings of the Paga Mining Co. Similar improvement in recovery is needed in the production of manganese.

Transporting all bank ore to the mills, as is now the standard practice, is a major item in operating costs and causes the accumulation of great quantities of waste at only a few localities. As the bank ore consists largely of clay, the greater part of this haulage would be eliminated if log washers were installed at or near the mines. In most operations it would be reduced 75 percent or more, for the products to be delivered to the mill would comprise only the log-washer concentrate—lump and jig ore—plus the coarser constituents screened from the log-washer overflow—feed for tables and flotation cells, and other material possibly subject to future beneficiation. The virtually barren clay tailings would be distributed in many small deposits rather than be concentrated in a few large ones. Disposal sites should be drilled, however, in order to avoid covering residual ores with waste.

BROWN IRON AND PYRITE

The deposits of brown iron ore are probably nearer economic exhaustion than the other secondary deposits, for the occurrence of the richer bank ore appears to be comparatively shallow. Most of the deposits show a downward increase in the abundance of jasperoid and barren clay and in some of them pyrite occurs at depths as little as 20 feet. Wherever pyrite occurs in waste at the brown-ore mines, it is most abundant in the least-weathered jasperoid and quartzite from the deepest parts of the openings, indicating a downward increase in the proportion of sulfide. Owing to the extensive mining of the brown-ore deposits and the probability that deeper mining generally is not likely to be successful, most of the remaining ore is probably limited to the lateral margins of the present mines, whose walls clearly show that a uniformly high grade of bank ore is not to be expected and that churn drilling is advisable to outline the ore that may be minable.

The large size of many of the brown-ore deposits, and the abundance of pyrite in the fresher rock from some of them, suggest that the deposits may be underlain by pyrite deposits of appreciable size. It is possible, indeed, that the sulfide deposits, which have never been mined or even prospected, may have greater potential importance than the remnants of the overlying oxide deposits. The size and structure of the sulfide deposits can be determined only by drilling. Such deposits are likely to occur largely in carbonate rocks, down-dip from the brown-ore deposits and adjacent to fault zones oblique to the strike of the rocks. Their major dimension may be parallel to the faults if the carbonate rocks are thick, or parallel to the bedding if those rocks are thin and are overlain by metashale.

OCHER, UMBER, AND HEMATITE

The ocherous and umberous residuum of the bedded hematite in the Shady formation is generally covered with a thin veneer of colluvium and soil. In some places both the residuum and the overburden contain residual masses of the hematite, which indicate the presence of the Shady formation. In most places, however, the extent and grade of the ocherous and umberous residuum, and even its presence in economic amounts, can be determined only by prospecting.

The larger ocher deposits were originally indicated by prominent yellow iron-stains in residual jasperoid boulders and in outcrops of the underlying quartzite of the Weisner formation. All such indications have been prospected, and the deposits thus found have been extensively mined. Where the residuum consists largely of umber and ferruginous clays darker than raw ocher, there is no such surface indication. It appears probable, therefore, that most if not all of the larger ocher deposits have been found, and that the reserves of better-grade material are probably rather small in proportion to the total amount of ocher already produced.

Where ocher is absent, or present only in small bodies too irregular to be mined, the bedded residuum consists in some places of chocolate-brown umber, uniform in color and texture, and in other places of ferruginous and quartzose clays, intermediate in color between ocher and umber and containing a smaller and more variable proportion of ferric hydroxide. The variable character of this material reflects the unevenly siliceous nature of the primary hematite, and its association with beds of dolomite. The umber and ferruginous clays are exposed on the footwall side of most of the larger barite mines, but there has been no prospecting to determine their thickness and range of grade. The thickness indicated at some of the hematite mines and prospects appears to be not more than 30 feet.

Some of the more uniform material has been shipped as umber from the mines mentioned on page 57, to be sintered for use as iron ore. There is some interest among potential consumers in expanding this use if an adequate supply of umber is available. Preliminary testing of thickness and grade may be undertaken where umber is exposed in place in the barite mines. Between these mines, the umber occurs in the zone of weathering as a tabular body immediately overlying the Weisner rocks, which in general are steeply inclined. Exploration between the barite mines can be done by trenching across the obscured zone of outcrop, and by drilling on its downdip side. The proportion of umber to valueless clay in this residuum is probably very uneven in the district as a whole. Nevertheless, enough residuum similar in color and texture to that shipped is exposed in mine workings to indicate that the reserves of umber are probably very large.

The shallow mining that has been done to recover the residual masses of hematite enclosed in the ocherous and umberous residuum is of comparatively small scale, and the recovery of hand-cobbed ore has been comparatively low. The results cannot be used to gage the possible reserve of ore below the zone of weathering. The rather persistent areal occurrence, in the southern part of the district, of the Shady formation between the Weisner and Rome formations probably indicates a similar persistence in depth. The outcrops of the formation have a total length, measured along their variable strike, of at least 18 miles; the length may be considerably more, for the presence of the Shady formation is not easily detected.

The very wide range in the proportions of specularite and quartz in residual ore and mine waste indicates that the hematite ore is not likely to attain commercial importance until a pacticable method of beneficiating it has been devised. Using the apparent average thickness of 30 feet for the Shady formation, a rough idea of the possible amount of hematite-bearing material available may be obtained by assuming that such material makes up about one-third of the formation at depth. The actual proportion seems to be much higher where the weathered beds are best exposed, but the hematite may be less abundant elsewhere. If the aggregate thickness of minable ore were only 10 feet, and the total length of the outcrops only 18 miles, the total reserve in the district per hundred feet of dip would be at least 3,500,000 cubic yards. The weight cannot safely be estimated, as the proportions and specific gravities of hematite and quartz differ greatly. A large part of the hematite has been destroyed by weathering to an average depth of at least 300 feet, but the reserve below that depth is evidently sufficient for large-scale mining if a profitable method of treatment can be developed.

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